Planning primates: A search for episodic foresight

PLANNING PRIMATES

A search for episodic foresight

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We then try to justify what we do by trying to make it sound as if it has some "useful" application. But, really, we do it because it is fun. Nature is entertainment - the greatest show on earth. And that is not trivial, because what is life, if it isn't fun? I think the greatest contribution we could make would be to help make life more interesting.

B. Heinrich (*Ravens in Winter, 1989*)

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Contents

1. Introduction

Anticipation and preparation are essential to life. Preparation for harmful or advantageous changes has been the concern of organisms since they originated. Indeed, constant adaptation to a changing environment is the hallmark of biology. Such adaptation in effect becomes preparation, and occurs both on phylogenetic and ontogenetic levels. The advent of nervous systems created a "fast track" for ontogenetic preparation for potential futures. A nervous system ensures a quick response to the environment. It incorporates reflexes and forms the basis for instincts. It stores experiences from the organism’s life in associative learning and memory, which can then be used to affect future outcomes. In a sense, the nervous system creates a model of vital parts of the organism's niche. The idea of the brain, or the mind, as essentially an internal prediction-making simulator of the outside world has been advanced by numerous theorists (e.g. Craik, 1943/1967; Dennett, 1984, 1991; Gärdenfors, 1996; Hesslow, 2002). In this sense all cognition is about the future; it helps the agent answer the question: Now what do I do? (Dennett, 1991, p 177). Actions then change the agent’s future. However, preparation in nervous systems remained, in effect, non-teleological, until the first deliberate plan arose.

There is one cognitive feature hypothesised to be especially important in making certain preparations for, and simulations of, possible futures: *episodic foresight*. If you would close your eyes you would, of course, stop reading. But if you did, it is likely that instead of the text, another sensorial-like world would take hold: a world constructed not by the photons reflected from physical objects into your eyes, but rather by things detached from current sensorial inputs, generated purely in your brain. Likewise, putting your fingers in your ears will not prevent you from hearing. There is a good chance that you will still hear your own monologue, perfectly performed even with a shut mouth (and probably, right now, you hear this text being read).

This inner world is often blurry and lacking in detail. At the same time, it has a spatiotemporal freedom not experienced in the ordinary world, in which Monday is bound to precede Tuesday and a minute is inevitably sixty seconds. In this world you could call people names, or stroke a lion and observe the response, without suffering the photon-world consequences. It is a world of opportunities otherwise unaffordable in flesh and blood. This is an ideal environment for testing actions and constructing plans. This foreseeing of potential future situations via detached phenomenal constructs is known as episodic foresight.

This thesis is about episodic foresight. It asks whether humans are alone in this conscious simulated world, or whether we have company: more precisely, do chimpanzees and orangutans master the allegedly uniquely human trick of constructing plans for possible futures in a sensorial inner world? The answer appears to be positive. However, note that the thesis is not about planning abilities in general, but about plans that are represented via phenomenal simulations.

The thesis then takes a step beyond the last common ancestor of chimpanzees and humans into the hominin line. Could it be that this inner world facilitated the evolution of symbolic language in our hominin ancestors? This last question remains unanswered; however, a hypothesis is offered for future empirical investigation.

1.1 The structure of the thesis

The main body of this thesis is six papers that have previously been published or accepted for publication. In order to put these in perspective, a chapter on comparative foresight precedes them: Chapter 2.

Chapter 2 begins with a review of the central theories and ideas that have shaped this scientific field, still in its infancy. It includes short descriptions of all hitherto published empirical studies on comparative episodic foresight, including my own; these are presented in full later in the thesis. Account is given of the methodological and theoretical critique these studies have received, as well as the published responses, out of which two are offered in full as Paper II and Paper V.

Up until that point, all the data, results and theories presented are presented with little regard to my own (empirically and theoretically based) opinions. The aim is to give the reader an unbiased picture of the field, its roots, and contemporary debate. Despite this objective, the result can still only be a result of my perception and analyses. The available literature still lacks a review of the kind presented here, with its detailed descriptions and historical links. What is chosen and what is omitted is a reflection of my own views.

After this historical overview, the chapter continues by discussing what could be regarded as the theoretical crux of the field: studying subjective experiences in non-linguistic species. Here my own opinions are in the forefront. (It should be noted that my opinions are also relevant to the articles following Chapter 2.)

The chapter ends with more speculative thoughts on the questions of human uniqueness and the relation of language to foresight. This discussion belongs within the chapter on comparative foresight, as the species in focus are not *Homo sapiens*. It relates to the last article in the thesis (Paper VI).

1.2 The aims and methods of the thesis

As the title suggests, this thesis is about primate planning. More specifically it investigates the abilities in chimpanzees and orangutans to plan with episodic foresight. To a lesser extent, it also considers how such abilities, coupled with cooperation, might have prompted language evolution in the hominin line.

From a phylogenetic viewpoint, the thesis mainly considers the evolution of episodic foresight in the lineage of hominidae. It is less concerned with identifying selective pressures that facilitated such an evolution than presenting an empirical catalogue (very incomplete) of foresight abilities in the great apes (but also early *Homo*). Non-hominidae species, especially those of corvidae, are discussed briefly in Chapter 2; homoplasic aspects of foresight in the hominidae-corvidae comparison are also given some reflection. However, these highly interesting questions are not within the scope of this thesis; they deserve an account of their own, elsewhere.

The methodology used in the great ape studies is the standard one of comparative cognition, including behavioural experiments and observations. The analysis of hominin cognition is based on the archaeological and paleontological literature, viewed in the light of cognitive and linguistic theories.

1.3 Papers in the thesis

The six papers included in the thesis are:

Paper I
Osvath M, Osvath H (2008) Chimpanzee (*Pan troglodytes*) and orangutan (*Pongo abelii*) forethought: self-control and pre-experience in the face of future tool use. Animal Cognition 11: 661-674. (With kind permission from Springer Science+Business Media).

Paper II
Osvath M (accepted manuscript) How farsighted is the Bischof-Köhler hypothesis? Animal Cognition.

Paper III
An excerpt, pages 57-60, from Osvath M (2009) In search of inner worlds: are humans alone in the mental world of possible futures? In: Högh-Olesen H, Tönnesvang J, Bertelsen P (eds) Human characteristics: evolutionary perspectives on human mind and kind. Cambridge Scholars Publishing, Cambridge, pp 44-64.

Paper IVa
Osvath M (2009) Spontaneous planning for future stone throwing by a male chimpanzee. Current Biology 19: R190-R191.

Paper IVb
Osvath M (2009) Supplemental data: Spontaneous planning for future stone throwing by a male chimpanzee. Current Biology online: www.current-biology.com/supplemental/S0960-9822(09)00547-8.

Paper V
Osvath M, Raby CR, Clayton NS (2010) What should be compared in comparative mental time travel? Trends in Cognitive Sciences 14: 51-52.

Paper VI
Gärdenfors P, Osvath M (2010) The evolution of anticipatory cognition as a precursor to symbolic communication. In: Larson RK, Déprez V, Yamokido H (eds) The evolution of human language: biolingustic perspectives. Cambridge University Press, Cambridge, pp 103-114.

1.4 Some words on words

Episodic foresight and *planning* are central concepts in this thesis. In both the comparative and the human field of research, a variety of terms have been used more or less interchangeably in the literature to denote the first mechanism e.g., *anticipatory cognition*, *episodic future thinking*, *prospective cognition, envisioning the future, episodic simulation of future events* and *mental time travel into the future*. In Chapter 2, the term *episodic foresight* is used consistently, following the suggestion by Suddendorf (2010). That suggestion is based on the brevity of the expression and the match it suggests with *episodic memory*, which may be regarded as the other part of the episodic cognitive system. *Foresight* is the act or power of foreseeing, with reference to the future. The papers in the remainder of the thesis do not use the term episodic foresight; however, the meaning of the terms used is equivalent.

The *planning* that is referred to is specifically that which results from episodic foresight; no other sense is intended if not stated. *Planning* as an everyday concept has many different connotations, so to preclude any possible confusion, a simple operational definition is given in Section 2.5.1. It will not be of any use to present it here, as it requires an understanding of episodic foresight, which must first be delineated.

2. Comparative episodic foresight

Numerous behaviours in a range of species might prepare for possible futures beyond current sensory scope. Many of these behaviours are not a result of cognition: for example, hibernation, food hoarding and nest construction might all be activated by species-specific releasing mechanisms or similar non-cognitive propensities.

Of course there is also cognition that results in behaviour affecting future outcomes. However it is not necessary that such cognition in itself concerns the future. The future is not, so to speak, borne in mind. Not all cognition that results in future-affecting behaviour need qualify as foresight. One clear example is memory systems: a memory ultimately exists to affect the future, but it is not about the future. As implied previously, cognition likely is very much an adaptation for dealing with the future. However, within the cognitive system, at least in some species, there are intentions *about* the future. One form of foresight especially could be regarded as cognition that is, very concretely, about possible futures. *Aboutness* is a philosophically tricky term, but that need not be of concern in this context, nevermind the problem of being about something that does not yet exist. In this context, "being about the future" means experiencing a mental episode that is acted upon as if it were a possible future for the subject. This has lately come to be known as *episodic foresight.* "Travelling mentally forward in time" is one popular way to describe this type of cognition, to capture its distinctiveness from other types of cognition that might affect, or even relate intentionally to, the future. The idea is old and perhaps also intuitive; however, the empirical framework for it arose in the 1980s.

2.1 From memories to time travels and foresights

The theoretical roots of cognitive foresight research are largely found in the field of memory research. In 1972, Endel Tulving proposed a distinction between semantic and episodic memory (Tulving, 1972). This division between a semantic and an episodic cognitive system created an essential framework for current comparative studies on cognitive foresight and memory.

The concept of semantic memory already existed at the time Tulving suggested the distinction. However, a contrasting term was lacking. In Tulving's words, a memory system was needed that could tell us what semantic memory was not, in the same sense that long-term memory is not short-term memory and *vice versa*. He argued that the appropriate counterpart to semantic memory was what he called *episodic memory*.

Semantic memory was exemplified within the domain of language, which is quite natural, given that the concept arose in the study of human psychology, with no reference to any comparative perspective. (Later the phrase *knowledge of the world* was proposed by Tulving (2005) as more fitting.) Tulving described semantic memory as a mental thesaurus of organized knowledge about symbols, their meanings, their referents and their relations, along with the rules, formulas and algorithms for manipulating them. Semantic memory was regarded as not registering perceptible properties of inputs, but rather the cognitive referents of such inputs. Episodic memory, on the other hand, receives and stores information on temporally structured episodes (or *events*), and the spatiotemporal relations between them. Episodic memory can *only* store perceptible properties, and always in autobiographical reference to the already existing content of the episodic memory store. Note that even if the two memory systems are considered as distinct, they most often operate in an integrated fashion.

Tulving gradually refined the defining contents of these memory systems: e.g., (Tulving, 1983; Tulving, 1985). Tulving thought of the semantic and episodic systems as *propositional*: i.e., they contained a truth-value as opposed to being merely procedural. Later, Squire and

Zola-Morgan (1991) defined the two memory systems as *declarative*. Perhaps the most notable theoretical addition was the hypothesis of different forms of consciousness accompanying and defining the two memory systems (Tulving, 1985). Tulving came to this idea when confronted by some clinical observations and experiments, mainly from his memory studies on a densely amnesic patient and from similar studies on healthy subjects, but also from David Ingvar's measuring of cerebral blood flow at wakeful rest in human subjects (Ingvar, 1979). Tulving coupled semantic memory with a type of consciousness he called *noetic* ("knowing"), in contrast to the *autonoetic* ("self-knowing") consciousness he hypothesised to be a necessary correlate of episodic memory. Noetic consciousness implies the ability to be aware of, and utilize the knowledge of, objects and events, and their relations, when they are not sensorially present. Semantic memory could be viewed as factual knowledge. Noetic consciousness is a feeling of knowing or familiarity. Episodic memory could be viewed as remembering, while autonoetic consciousness is a re-experiencing of a past event (Gardiner, 2001). To elucidate the distinctive quality of autonoetic consciousness, Tulving used the metaphor of *mental time travel*. Autonoetic consciousness makes it possible cognitively to travel in time and phenomenally to re- or pre-visit events.

Noetic consciousness was never empirically confirmed but instead inferred from observations of the workings of autonoetic consciousness in the episodic system. The main evidence for autonoetic consciousness Tulving derived from the amnesic patient later to be known as K.C. This patient suffered from an unusual form of brain damage, due to a motorcycle accident. K.C. had retro- and anterograde (episodic) amnesia and was unable to remember anything at all about personal events. At the same time his language skills, intelligence and general knowledge (i.e., semantic memory) were, it appeared, largely intact. K.C. could not recall a single episode of his life, even though he did have some semantic knowledge of his past. He could recall (some) facts; but otherwise his past was a closed book, and in no way could he re-live it. That is to say, K.C. had no *phenomenal* experience of his past, not even from the minutes immediately preceding the present. When K.C. tried to think about his past – or, more interestingly, about his future – he described his mental state as "blank". When prompted to describe this blankness, he compared it to being asleep. K. C. shows a peculiar mix of disability and high-level functioning. He easily performs a number of daily routines: finding appropriate kitchen utensils, playing computer games, watching TV, conversing with people. His theory of mind appears intact, (Rosenbaum et al 2007). He does need reminders, as he does not otherwise know what he will do next after finishing an activity. Naturally, he cannot manage his life without supervision. Since these initial findings, K.C. has been thoroughly investigated in a number of studies. (For a review see Rosenbaum et al, 2005.) K.C's cognitive deficits have been found in other patients, one of whom will be examined in the following section.

Tulving corroborated his theory using healthy subjects who were asked to respond to things they knew or remembered; these studies confirmed a distinct difference between knowing and remembering.

Later Tulving found it necessary to hypothesise yet another form of consciousness in order to account more precisely for how humans utilise episodic cognition in mental time travel. This type of consciousness he referred to as *chronesthesia* (Tulving, 2002), the awareness of subjective time. It differs slightly from autonoesis in that it emphasises the sense of (subjective) *time*, whereas autonoetic consciousness is concerned with the sense of *self* in time. According to Tulving, the self can be conceived without a time dimension, and time can be considered without a self: hence the distinction. However, chronesthesia remains to be disambiguated in any meaningful way for comparative studies: does it have distinct behavioural correlates, or is it just one consciousness too many?

2.1.1 Mental time travel and the Janus hypothesis

As noted in the previous section, K.C. had an inability to think phenomenally about his personal future that was identical to his inability to think phenomenally about his past. In fact, he described the blankness of mind to be the same kind in both memory and foresight attempts. Even if one clinical case is not decisive enough to base a theory on, K.C.'s case raised the possibility that episodic memory might be merely one of the functions of the episodic cognitive system. Foresight -- mentally constructing potential personal futures -- might be the other function. This possibility is reflected in Tulving's mental time travel metaphor, an idea that Tulving and colleagues briefly revisited in 1997 (Wheeler et al, 1997). In the same year that Tulving published his seminal paper on memory and consciousness, David Ingvar, whose work (Ingvar, 1979) partly inspired Tulving, suggested the idea of *memories of the future* (Ingvar, 1985). Ingvar identified certain prefrontal cortex areas in humans as the place where conscious thought of both past and future are facilitated. He observed high activities in these areas during wakeful rest. The key cognitive characteristic of this state is that thoughts wander, into past events or potential future ones, or just into daydreams. In this state mental past and future appear effortlessly to rub shoulders. Ingvar described the store of future scenarios that arises during wakeful rest as memories of the future. Brain studies on wakeful rest are ongoing, and a so-called *brain default-mode* has been hypothesised (e.g Raichle et at, 2001; Christoff et al, 2004; Mason et al, 2007). This is the default activity in a brain at wakeful rest. Interestingly it involves similar brain regions to a brain actively simulating the past or future. From a comparative perspective, it is noteworthy that such a brain default-mode has recently been found in chimpanzees (Rilling et al 2007), of which more will be said in Section 2.5.2.

Despite these early proposals of an episodic temporal continuum, it was not until 1997 that the idea of mental time travel became the subject of serious theorising. In *Mental time travel and the evolution of the human mind*, Suddendorf and Corballis suggested a firm cognitive connection between episodic memory and episodic foresight (Suddendorf and Corballis, 1997). They argued that the ability for mental time travel is unique to the human lineage and an integral element of our cognition. They speculated that episodic memory might be a design feature of the ability for foresight. Episodic memories do not prove their value by accurately recording the past. They are prone to error and are easily manipulated (e.g., insertion of false memories). Episodic memories are best understood as approximate phenomenal reconstructions and not snapshots of the past. Such a construction of a conscious sensorial model of a displaced episode might be of most value for the fitness of an organism in the face of potential future alternatives. The essential building blocks of such a future-model would be both episodic and semantic memories, arranged in new constellations. A decade later, Suddendorf and Corballis published an updated version of the article, including new evidence for the temporal duality of the episodic system (Suddendorf and Corballis, 2007a).

In 2005, Dudai and Carruthers reminded contemporary neurocognition researchers of the ancient historical roots of the idea of an intimate connection between memory and foresight (Dudai and Carruthers, 2005). This insight resulted in yet another poetic turn-of-phrase in the field of episodic cognition: *the Janus hypothesis* (Suddendorf and Corballis, 2007b), which captures the close link between mental time travel into the past and into the future. It borrows its name from the double-faced Roman god Janus, the god of the new year, who simultaneously keeps one face to the future and one to the past.

In recent years a number of neurocognitive studies have confirmed that conscious foresight and episodic memory rely heavily on common, basic neurocognitive components, notably parts of the pre-frontal cortex and the medial lobes. In 2007, there was an upsurge in articles on the subject, and the discovery's importance was acknowledged as one of the scientific breakthroughs of the year (Science, 2007, pp. 1848-1849). Hassabis and colleagues reported on the highly restricted ability for imagining the future in five patients with amnesia caused by hippocampal damage (Hassabis et al, 2007a). In an fMRI study, 16 healthy humans were examined when engaging in episodic memory retrieval task and when imagining future events (Addis et al, 2007). The authors found overlap between certain brain regions in the two conditions. Another fMRI study investigated the neural substrates just of envisioning the future (Szpunar et al, 2007). The same year, a number of reviews and opinion pieces on the issue were published. In one of them, Buckner and Carroll submitted that, based on recent evidence, there exists a *core brain network* for episodic memory, foresight and theory of mind (Buckner and Caroll, 2007). This network was hypothesised to involve frontal and medial temporal-parietal lobe systems. Hassabis and Maguire offered a somewhat different view in direct response (Hassabis and Maguire, 2007). In their review of the neurocognitive data, they identify a *scene construction* network, while downplaying the "self" that is involved in episodic memory and foresight (although they argue that the scene construction network is part of such memories and foresights). Later the same year the authors published a fMRI-study supporting their claim (Hassabis et al, 2007b). In another review, Schacter and Addis put forward the *constructive episodic simulation hypothesis*, which in large part restates the idea of episodic memory being the toolbox for foresight (Schachter and Addis, 2007). (For a more recent review by these authors, see Schacter et al, 2008).

Prior to 2007, at least two other neurocognitive studies were conducted addressing the connection between memory and foresight. Okuda and colleagues conducted a PET-study on healthy subjects, comparing cerebral blood flow when the subjects talked about the past and when they talked about the future (Okuda et al, 2003). This study, similar to later ones, suggested common brain regions for the different tasks.

The other study, which might be of more interest from a comparative perspective, was conducted on a patient referred to as D.B. D.B., like K.C., suffered from retro- and anterograde (episodic) amnesia (Klein et al, 2002). His condition was a result of hypoxic brain damage caused by a heart attack. D.B. could not remember a single event from his past; however, his semantic memory seemed unaffected. When asked a battery of questions about his personal future, he produced either confabulatory answers or none at all; he made a significantly lower number of correct responses in comparison to a healthy control group. However, when he was asked questions about a future unrelated to his own person, e.g., questions on global politics or technology, his answers were at the same performance level as the control group. His foresight abilities were compared to his memory abilities in the same two conditions (personal vs. impersonal); their success rates were found to mirror each other. The authors took the personal vs. impersonal distinction to reflect the difference between the episodic and semantic cognitive system.

Evidence for a common underlying cognitive structure for memory and foresight comes also from the developmental perspective. Atance and O'Neill introduced the term *episodic future thinking* in 2001, on the basis of available developmental data (Atance and O'Neill, 2001). However, the question of when the capacity for mental time travel emerges in human development became of more intense interest only recently, in light of the debate over non-human mental time travel (Atance, 2008). The few studies conducted on children's foresight suggest that the development of this ability roughly coincides with the development of episodic memory. Episodic foresight abilities seem to appear at the age of four to five years; three-year-olds either do not have this ability or only have rudiments of it (e.g. Busby and Suddendorf, 2005; Suddendorf and Busby, 2005; Atance and Meltzoff, 2005). Busby and Suddendorf (2005) compared children's ability to produce a correct answer for what they did yesterday to their ability to produce one for what they will do tomorrow. They found a correspondence for both failure and success in the two tasks depending on the age of the child. Further studies of developmental data have revealed that with growing age, in adulthood, the details of episodic memories and of episodic foresights decline, in parallel (Addis et al, 2008).

There appear to exist phenomenological similarities in memory and foresight. Sensorial, contextual and emotional details seem to be qualitatively similar to each other (D'Argembeau and van der Linden, 2004). Moreover, the phenomenal quality of memory and foresight is consistent within individuals: those with less phenomenal content in memory experience equally sparse details of the future, and those with rich experiences have them in both modes (D'Argembeau and van der Linden, 2006).

No less interesting, as will be apparent further on, is that there is an overlap between memory and foresight in the comparative context as well. Non-human animals that form complex memories appear also to be capable of complex foresight.

Obviously, there are differences between the systems underlying memory and foresight; however, these do not challenge the validity of the Janus hypothesis. (For a review of these difference see Suddendorf, 2010).

It needs to be mentioned that the data supporting the Janus hypothesis probably fit into a larger scheme of phenomenally conscious simulations in the brain. Different avenues of research have pursued different aspects of this phenomenon of simulation, from mental imagery and affective forecasting to counterfactual thinking, action simulation and so on. Only recently has there been an effort to integrate these different perspectives in a book volume, "Handbook of Imagination and Mental Simulation" (Markman et al, 2009). The number and theoretical diversities of peer commentaries on Suddendorf and Corballis' article on mental time travel in Behavioral and Brain Sciences (Suddendorf and Corballis, 2007a) is a further sign of the broader attention that this field has received. However, a unifying theory has still to come.

2.2 Autonoetic consciousness and cognitive functions

The episodic cognitive system with its defining autonoetic consciousness is of critical concern in comparative studies on foresight. The semantic and episodic systems have several functional features in common. They rely on fast encoding, enable single trial learning, and code their information declaratively ("knowing that") and propositionally (i.e., having a truth value) (e.g. Tulving, 2005). In a comparative context, any behaviour that reflects only such common functions is by virtue of parsimony hypothesised to result from semantic cognition. This is because the semantic system is regarded as phylogentically older than the episodic system.[1] Therefore when probing for episodic foresight in non-human animals it is essential to know those functions that are specific to the episodic system.

Usefully a number of such properties have been identified (e.g. Wheeler et al, 1997; Tulving, 2005; Suddendorf and Corballis, 2007). Those relevant to this context are the ones that can be inferred from behaviour in non-linguistic animals: i.e., self-related foresights, particularity containing foresights, flexible foresights, and foresights relating to novelties. These functions are closely related to each other, something that becomes clear when analyzing them in relation to autonoetic consciousness, of which they appear to be an immediate consequence.

The defining feature of the episodic system is phenomenal experience detached from current sensory inputs: mental simulations of e.g. sight, sound, smell, or touch. These experiences – or mock sensations – are expressions of the autonoetic consciousness, which only arises with the episodic system. Autonoetic consciousness might not necessarily be regarded as a cognitive function in itself; however, a range

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[1] This is because the episodic system appears to be dependent on the semantic system and not *vice versa* (e.g. Tulving, 2005).

of functional properties appears to follow directly from it, as we shall see.

Episodic cognition concerns a subject who "travels" mentally. The episodes are experienced autobiographically; or, more accurately, from a first-person perspective, as it is possible to "travel" to episodes beyond the extent of one's own lifetime. This subjective aspect is evident when considering that an experience is by definition the property of an *experiencer*. No matter if one is imagining being someone else: the experiences can only be had from a first-person perspective. The semantic system, on the other hand, is not personal in that sense: it is about knowledge of facts. Even if such facts might be about the person, like one's shoe size or the place of one's birth, they are still not personal experiences. Known personal facts are no more experientially personal than known impersonal ones: they do not or need not involve a sense of self. This means that the possessor of autonoetic consciousness should be able to make experiential foresights about a personal future, such as future affects; whereas one with merely noetic consciousness could not perform such foresights (as corroborated by the aforementioned study by Klein et al, 2002). Nevertheless, it should be noted that the literature on autonoetic consciousness contains only very limited discussions on what self-knowing more precisely refers to: what precisely is meant by the *self* and what is known about that self? Some have hypothesised that the simulation of sensorial impressions detached from current inputs is what constitutes the feeling of a self as humans sense it (e.g. Osvath, 2008). That would make the self in autonoetic consciousness presupposed in a way not subject to rejection or amendment, as the self might seem intrinsic to such consciousness: the self just happens, so to speak. Without going into details, this might not however prejudice cruder operationalisations of the concept.

Another result of phenomenal experience is that the episodic system concerns particularities, as opposed to the regularities of concern to the semantic system. An episodic memory or a foresight can only involve what is experienced and not abstractions directly. This is because sensations in the real world result from particularities (e.g., objects) in the environment. If all swans were indeed white, your experience of a swan could only be about the particular white swan you were currently observing; the regularity (fact) of the whiteness of swans is not a sensorial experience. This does not mean that any experience is not based on a mass of generalised knowledge; and, conversely, it does not imply that the particularity of the experience does not influence generalised knowledge: when a black swan is observed, one's generalized knowledge changes. This suggests that the semantic and episodic systems interact. Nevertheless, an imagined bird will always be a particular bird. Even if it is a bird prototype based on knowledge of many different types of birds, it cannot be e.g. both a penguin and an ibis at the same time. (It might be a mix, but it still must be a particular mix.) With respect to foresight, this means that the future model must be about a particular object or situation. So, in this sense the episodic system is explicitly contextual and the semantic is not.

That the episodic system constructs particular episodes is part of why it can relate to novelties and be flexible. The other reason is that episodic-system constructs, unlike the constructs from the real sensory system, are detached from current sensory inputs when generated. They rely on a store of previous sensory experiences that, in principle, can be arranged in all logically possible ways. Even if one believed that all swans were white, and even if one only had a store of episodic memories of white swans, it would still be possible to imagine a black swan, so long as the memory store contains sensory information of blackness and swans. This is why it is possible to use episodic foresight to plan for events that have never as yet been experienced, with the foresighted novel combination of elements. The flexibility of the episodic system relates closely. The possessor of an episodic system should, in principle, be able to use it effectively in (nearly) any potential context – in theory that is; in practise there is most likely constraints.

2.2.1 A mechanism of autonoetic consciousness in future oriented decisions

It is easy to imagine the benefits of an ability to simulate potential futures. However, the question remains how such simulations would aid the agent in making decisions within the current situation in view of a potential future one: i.e. planning. What is it that tips the scales with such simulations from current- to future-oriented behaviour? It is not biologically much value having a cognitive ability that does not result in any fitness raising behaviour. The flow of plans, memories and daydreams that accompany the mind in wakeful rest is interesting, but the ability has hardly evolved as mere entertainment. This question has received little serious attention in the comparative foresight field. Yet identifying a potential mechanism behind episodic-system-based decisions could prove fruitful in empirical research, as such a mechanism might then be targeted in controlled experiments.

It has recently been suggested that mental time travel might provide a motivational “brake” on current drives in favour of delayed rewards (Boyer, 2008). The sensory experience in an autonoetic episode evokes an emotion related to that episode. This emotion competes with whatever other emotions were prior to the episodic construct. This brings the future into the present: for example, a choice between immediate and delayed satisfaction becomes a choice between two current emotions. When the emotion evoked by the sensory simulation induces a sufficient motivation for action, in effect a decision for the future is made. It is a trick of the cortical structures on the sub-cortical ones, fooling them into reacting emotionally and motivationally to the simulations as though they were the real thing.

One can appreciate that the simplicity of this idea would fit in well with an evolutionary account of cognition, so that decisions for the future rely mainly on evolutionary more primitive systems of sensory inputs and emotions. Note that even if such future-oriented decisions rely on some form of phenomenal consciousness, that does not necessitate any complex, self-reflective consciousness: in particular, the decision need not be subject to conscious reflection or evaluation. Rather, it can be a “simple” low-reflective act based on the strongest motivation induced by the strongest emotion. Not only might the reason *why* the emotions arose be undetectable by conscious thought, so might the bare fact that an emotion has indeed arisen. Going further, the creation of an episodic construct in a given situation could be the result of a non-conscious process. A choice or decision based on autonoetic simulation could be just as consciously blind as one made entirely "in the moment" with no such simulations (e.g. Johansson et al, 2005).

Determining the number and importance of non-conscious processes involved in episodic foresight is most likely a non-trivial problem. However, as will be apparent in the following sections, the comparative foresight field has so far been pre-occupied with the prior question of the existence of autonoetic consciousness in non-humans. Autonoesis does seem to make it possible for humans to achieve things not easily done without it.

2.3 Theoretical origins of the debate on comparative episodic foresight

Thus far, the fundamental question regarding comparative mental time travel has been whether episodic cognition is exclusive to humans or not. For centuries prominent scholars have regarded the central cognitive mechanisms required for mental time travel to be restricted to humans. One of the first academic claims made on the uniqueness of the human recollection mechanism is traced to Aristotle (Menzel, 2005). Descartes is often regarded as an early and influential source of the assumption that animals are devoid of the type of consciousness that defines mental time travel (e.g. Metcalfe and Kober, 2005).

Current discussions in the field of comparative episodic foresight are heavily influenced by views put forward by Wolfgang Köhler around the 1920s. Köhler was a gestalt psychologist and one of the pioneers in experimental comparative cognition on chimpanzees. At his anthropoid station in Tenerife between 1913 and 1917, Köhler studied the cognition, especially as it related to insight, of a group of chimpanzees . These studies were published in a book in 1917, which was published in English in 1925 as "The Mentality of Apes" (Köhler, 1925). In this later version he added an appendix, previously published in the journal Psychologische Forschung (Köhler, 1921). It is mainly this paper that has attracted attention from the field of comparative foresight. Köhler described his observations of chimpanzees anticipating events that were, he said, planned acts of the animal itself. For example, one of his subjects, Sultan, worked for an extended time fashioning a wooden board in order to make it fit into an apparatus containing a reward. However, the reward was always visible in the cases Köhler studied: i.e., the goal of the planning action was available to give sensory feedback. Köhler argued that it would be an even higher achievement if the ape could make preparations for events that are not yet within sight. He did not observe such behaviour; on the other hand, he acknowledged that he never deliberately arranged any situations where it could be observed. He realised the importance of conducting such experiments, and he believed they would have implications for our understanding of farsightedness in human culture. (This was at a time when chimpanzee culture still had not been recorded). Köhler even suggested an experimental protocol for such a study, which will be returned to in Section 2.5.1. For now it is enough to note that it took over eighty years before any experimental attempts where made.

The contemporary claims of human uniqueness specifically with respect to mental time travel date to Tulving who, as earlier noted, is the father of the concept (1983, p 1): "Remembering past events is a universally familiar experience. It is also a uniquely human one." Tulving later (2005) admitted that his aim with that statement was actually to emphasise the distinctiveness of episodic memory by contrasting it to cognition in the rest of the animal kingdom: a graphic point in a time still influenced by behaviourism. Nonetheless, Tulving (2005) maintained his position that episodic cognition, including foresight, is strictly human, supporting the claim on the absence of evidence of the contrary.

However, it was not Tulving's work that directly prompted much of the heated debate over comparative episodic forethought (or comparative mental time travel in general). Instead, it was the aforementioned, seminal article by Suddendorf and Corballis (1997) that integrated the uniqueness assumption into a theoretical framework of human cognitive evolution. The authors put forth a hypothesis they dubbed the *Bischof-Köhler hypothesis*. This hypothesis relates to the future-oriented aspect of mental time travel, and was originally expressed in the following way: "...animals other than humans cannot anticipate future needs and drive states and are therefore bound to a present that is defined by their current motivational state." The hypothesis is based on the assumptions of Bischof (1978, 1985) and Bischof-Köhler (1985), who were inspired by the writings of the previously mentioned Köhler: hence the name of the hypothesis. It was based on the lack of reports of non-human animals exhibiting planning behaviours of that kind, as determined by reviewing the primatological literature and consulting a previously conducted survey (Suddendorf, 1994) on 73 leading primatologists, who were asked for anecdotal reports that would contradict the hypothesis. The Bischof-Köhler hypothesis has turned into a cornerstone in contemporary comparative episodic foresight studies. Since the publication of the article, Suddendorf and colleagues have maintained their standpoint despite empirical challenges to the hypothesis (eg Suddendorf and Busby, 2003a; Suddendorf and Busby, 2003b; Suddendorf and Corballis, 2007; Suddendorf and Corballis, 2008; Suddendorf, Corballis and Collier-Baker, 2009; Suddendorf and Corballis, 2009).

William Roberts, following on from Köhler, Tulving and Suddendorf, suggested a similar idea on human uniqueness in temporal cognition. In 2002 he published a paper called: *Are animals stuck in time?* (Roberts, 2002). Here he advanced the so-called *stuck-in-time hypothesis*, a term inspired by Vonnegut's novel "Slaughter-House Five". Roberts focused on the question whether animals have a sense of temporal succession. He regards this as central to mental time travel. Roberts reviewed a large number of animal studies related to temporal abilities: for example, associative learning, circadian rhythms, working memory, reference (or semantic) memory, and food-hoarding patterns. He also examined the evidence for animal episodic memory and anticipation of future events. His conclusion was that many animals are highly time sensitive; however, he found no evidence for animals possessing a sense of time (i.e., *episodic cognition* in Roberts' interpretation). Roberts has maintained this view; however, lately he has leaned more towards agnosticism, not least it appears due to his own empirical studies (e.g. Roberts, 2006; Roberts and Feeney, 2009).

Numerous others have assumed that the ability to plan for a future beyond the current situation, or to imagine the future, is uniquely human. However, their impact has been negligible on the comparative cognitive field.

One theorist, not primarily concerned with the human-uniqueness-question in planning abilities, is Agneta Gulz (1991)[2]. She made a theoretical examination of the cognitive requirements of planning. Unaffected by Tulving, and the ideas underlying the Bischof-Köhler hypothesis, Gulz identified two distinct types of planning: *immediate* and *anticipatory* planning. Immediate planning is planning related to a current or immediate interest and to a corresponding motivation for action. Anticipatory planning, on the other hand, is planning related to potential future problems or interests uninfluenced by the current motivation. It was this theory that initially inspired my work (e.g Osvath and Gärdenfors, 2005; Osvath and Osvath, 2008 [Paper I]).

It should also be mentioned that Richard Byrne (1995) devoted a chapter on planning and thinking ahead in his book "The thinking ape". Interestingly he also used the term anticipatory planning, with more or less the same meaning as in Gulz' work. He presented an

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[2] Gulz did however note that planning for future interests appears to be uniquely human.

anecdote on adult chimpanzees killing a leopard cub, taken at purpose from its mother. Byrne cautiously speculated that this might have been an act of anticipatory planning (as adult leopards hunt chimpanzees).

2.4 Studies on episodic memories in non-human animals

The methodological concerns and other discussions surrounding comparative mental time travel initially arose in the context of animal memory studies, which motivates a brief recapitulation of that field.

Some of the earliest structured investigations of episodic cognition in animals were made on the memory capacities of Western scrub jays (*Aphelocoma californica*), a species of corvid birds (Clayton and Dickinson, 1998, 1999; Clayton et al 2001, Clayton et al 2003a). The authors aimed to follow Tulvings' (1972) behavioural criteria for episodic memory, as derived from his statement that episodic memory (p 385):"...receives and stores information about temporally dated episodes or events, and temporal-spatial relations among these events". The studies assessed whether the birds could flexibly integrate the components of the *what*, *where* and *when* of a past event in their memory. The content of that memory was inferred within the context of caching, a setting chosen for its ethological validity: food caching seems to be ubiquitous in corvids. The birds were offered an opportunity to cache different food items (*what*), at different locations (*where*) and with different decay times (*when*), thus involving each of the different components. Afterwards, the birds were tested on whether they behaved optimally in relation to the *what-when-where* information in their recovery of the caches. The findings revealed that if the delay between the caching and the recovery was short, the favoured, but rapidly decaying, waxmoth larvae were searched for before the non-perishable, but less favoured, nuts, whereas the birds went for the nuts if the delay was longer (i.e., the larvae had time to decay). In a control-group setting the larvae did not decay, regardless of the delay. In this case, the control subjects consistently searched for the waxmoth larvae.

Figure 1 A scrub jay is about to cache its favourite food in an experiment at University of Cambridge. (Photo: Ian Cannell)

Other explanations, such as familiarity-based recognition of the most recent caching location, were ruled out in various controls. In another experiment, it was shown that the scrub jays would flexibly alter their search preferences at one caching location, after they received experience from another location where the preferred food had decayed faster than they expected: that is, after this experience, they searched for the cached *non-perishable* food in the first location (Clayton et al, 2003a). (For a more comprehensive review of the series of experiments on scrub jay caching memory, see de Kort et al, 2005.)

Since these seminal experiments a number of studies using the *what-where-when* criteria have been conducted not only on other species of birds, but also on mammals and insects (Babb and Crystal, 2005, 2006; Bird et al, 2003; Ergoroul and Eichenbaum, 2004; Feeney et al, 2009; Ferkin et al, 2008; Hampton et al 2005; Henderson et al, 2005; 2006; McKenzie et al, 2005; Pahl et al, 2007; Roberts et al, 2008; Skov-Rackette et al, 2006; Zhou and Crystal, 2009; Zinikivskay et al, 2009). Most of the results favour the animals being able to relate to some or all of the *what-where-when* components, although some results are negative and some studies seem to contradict others studies of the same species.

Of more interest in the context of this thesis are the few experimental attempts on great apes. One experiment assessed whether a gorilla (*Gorilla gorilla gorilla*) could remember *who* did *what* (Schwartz et al, 2002). This experiment was based on a system of cards that represented five food items and two animal keepers. After different periods of delay, the gorilla had to report, by using the cards, on who gave him a certain food. The results were positive; however, the question remains whether the behaviour was a result of actual recollection or only of familiarity-based recognition of the cards (Schwartz, 2005; Schwarz et al 2005). Menzel (2005) reported on a chimpanzee displaying memory of a food item that was hidden in a specific location sixteen hours prior to the opportunity to indicate this to a caretaker, using lexigrams. However, to date there is only a single published study investigating all three components of *what-where-when* in great apes. Martin-Ordas and colleagues devised two experiments following some of the setups from the scrub jay studies; the subjects were chimpanzees (*Pan troglodytes*), orangutans (*Pongo abelii*) and bonobos (*Pan paniscus*) (Martin-Ordas et al, 2010). In an initial experiment, the apes were allowed to observe the hiding of two different food items at different locations (though on the same table). One of these items was preferred over the other. The preferred item was a piece of frozen juice and the less favoured one was a grape. When the juice melted, it disappeared from its location and became unobtainable. The apes were tested in two retention intervals: one after five minutes and one after an hour. The apes chose to retrieve the juice after the five-minute delay; however, they reversed their preferences after an hour. These results clearly indicate the ability to form memories integrating *what-where-when* components. The second experiment investigated whether the apes could explicitly encode for the *when* component without it being cued by the *where* component: that is, the single table that contained the different food items could be regarded as the *where* component prompting the retrieval of the other two components, as they were more or less integral to the table. To remedy this potential confound, the apes were allowed to observe the two different food items being hid at two different places at two different times. First, the two food items were hid in a table in one room an hour prior to the other hiding event, which included the same kind of food items in another room with another table. Five minutes after the last hiding event, the apes were allowed to choose from the two tables in succession: either from the “oldest” table first and the freshly baited table second, or the other way around. If indeed the ape could form integrated memories with distinct respect to the *when*-components, then they would go for the grape from the table baited an hour before and for the juice from the table baited five minutes before. This is what the apes did.

2.4.1 Methodological and theoretical concerns

Despite the number of animal studies related to the episodic memory system, there is a crux in the interpretation of the results. The studies do not tell us whether the memories of the different species truly are episodic according to the current definition, as they do not attempt to address autonoetic consciousness. When Clayton and colleagues formulated their criteria, they explicitly followed the early Tulving (1972), who did not yet include subjective experience in the definition. The choice of the early definition of episodic memory was a result of their distinction between a phenomenological and a behavioural criterion. They found it empirically viable to adhere only to the latter (Clayton and Dickinson, 1998; Clayton et al, 2003b; Clayton et al, 2009). They suggested that the type of memory detected in studies that followed the behavioural criterion should be called episodic-*like* memories: i.e., not truly episodic due to lack of evidence for autonoetic consciousness. However, one could question their choice of terms in distinguishing between phenomenological and behavioural criteria, as Clayton and colleagues do not of course mean that the phenomenological criterion is strictly private, that only you yourself can decide whether you are phenomenologically aware. Rather they intend a linguistic criterion, where e.g. a verbal report on a memory would meet the criterion. Linguistic reports are certainly behaviours, even if they are rare in nature. The notion of "episodic-like" was challenged by Suddendorf and Busby (2003), partly, although not explicitly, on this basis. Because Suddendorf and colleagues claim that mental time travel, including true episodic memory, is uniquely human, they are forced to argue that this claim must be empirically testable. (Otherwise it would not be much of a hypothesis.) They suggest that it is possible to detect mental time travel, or episodic memory, either by linguistically training animals or by eliciting non-linguistic declarations, such as a motor re-enactment of an event. At the same time, they question the *what-where-when* components as even being necessary to episodic cognition, as it appears perfectly possible to recollect events vividly without access to accurate *when* and *where* information. Instead, they propose *www-memory* as a more neutral and descriptive term of the memories inferable from studies following the behavioural criteria of Clayton and colleagues. Tulving (2005) was similarly unhappy with the notion "episodic-like", because settling with this concept would mean not pursuing an interesting and biologically evolved feature of episodic cognition: autonoesis. As will be apparent in the following sections, this division of views between what *is* and what is *not* empirically tractable is central to the issues of comparative episodic foresight.

2.5 Studies on episodic foresight in non-human animals

A memory refers to what has already happened, while a foresight refers to something that has not happened yet. This straightforward distinction implies important methodological differences in experiment design. In theory at least, it is simpler to control for what has not happened to an animal than what has happened to it. When a memory is encoded, a range of actual physical stimuli in the current situation shape the memory, whereas in forming a foresight, the potential future situation cannot possibly have any direct influence on the behaviour. It is the situation in which the planning takes place that matters, and this is what foresight studies must control for. Therefore it is somewhat less challenging – though still far from clear-cut – to formulate non-linguistic behavioural criteria for episodic foresights than for episodic memories, and so take into account some of the previously mentioned functions derived from autonoetic consciousness.

2.5.1 Non-linguistic behavioural criteria for episodic foresight

All of the current non-linguistic criteria involve planning, as planning appears to be the most tangible way to identify foresight behaviourally. In principle foresight could be conducted without any, or without any distinguishable, behavioural correlates: one can think about a potential future and not act on it. Likewise, a future-oriented simulation could be used as mental rehearsal of an upcoming situation, which would be hard to disambiguate with any behavioural measure. In the context of episodic foresight, *planning* can be given a simple operational definition: episodic foresight that results in a decision followed by an action (in effect, a future-directed decision). One could of course define planning as thoughts on temporal sequences, including sub-goals and end-goals, which might occur *without* leading to an action. However, such cognitive operations would be hard to measure accurately in non-linguistic behaviour.

From the time Wolfgang Köhler speculated on whether there might be foresight abilities in chimpanzees and how to test for them (Köhler, 1921), it was 64 years before the first ideas on mental time travel and episodic foresight were published. Nevertheless, his proposal for a non-linguistic foresight test is worth looking at, as it comes close to, and might even have inspired, contemporary proposals on behavioural criteria. Köhler's chimpanzees were used to stacking boxes on top of each other to reach food dangling on ropes from the ceiling. His proposal was to take such a box-competent chimpanzee and keep that ape in a room full of boxes while deprived of food. Subsequently, this individual would be allowed into another room with plenty of unreachable food, but without access to the first room. Then, the hungry ape would be allowed back again to the first room with the boxes. The procedure would be repeated until such point (if ever) that the chimpanzee made the connection between the two circumstances, only one of which was visible at a time. The key behaviour to be observed for would be a transportation of the boxes when allowed over to the food room. Köhler regarded this as an experimental core whose details could be varied in an actual study. This protocol might well have inspired some recent proposals of behavioural criteria. A two-room paradigm, in unpublished work by Suddendorf (now available on the internet, Suddendorf, 1994), has a lot in common with Köhler's idea, although it is a bit more elaborate and e.g. takes drive states into consideration. However, only one criterion (Osvath and Osvath, 2008 [Paper I]) has yet implemented the additional ideas of Köhler that he described immediately after his experiment proposal. Köhler thought that it would be a great achievement if the apes could disregard a strong momentary interest in favour of a mere expectation of future advantage

The first published contemporary attempts at non-linguistic behavioural criteria for foresight appeared in 2003 (Clayton et al, 2003b) and in 2005 (Suddendorf and Busby, 2005; Tulving, 2005). These criteria have a lot in common, and two of the sets stem from the same source.

Clayton and colleagues based their criterion for foresight on their criterion for episodic-like memory (Clayton et al, 2003b). It contains three main elements: *content*, *structure*, and *flexibility*. The content element is about *wha*t will be anticipated, *where,* and *when*, on the basis of previous experience. The structure element requires that the *what-where-when* components be integrated into a representation. The flexibility element refers to the way that the semantic and episodic systems interact, so that the episodic system must rely on flexible deployment of information. These elements then relate to their definition of future planning (p 690):"…future planning is the ability to anticipate future needs and desires, independent of current needs and desires, and over longer timescales than the short timescales sufficient for instrumental responding such as lever-pressing for food reward."

However, a word of caution: this criterion by Clayton and colleagues might not be about *episodic* foresight as such. Just as with memory, these authors are reluctant to postulate the subjective experiences that autonoetic consciousness entails (as will be discussed at length in Section 2.6). Instead their criterion should perhaps be viewed as detecting episodic-*like* foresight, or perhaps *semantic future thinking* (a term returned to in section 2.6.6).

Tulving (2005) is somewhat more explicit with his non-linguistic criterion. He relates it to an Estonian children's story. In this tale, a little girl dreams one night of being at a friend's birthday party where all the guests who brought their own spoons are served chocolate pudding. Unfortunately, the girl is not among the lucky ones. Next day when she goes to bed, she brings a spoon with her in anticipation of the forthcoming chocolate party. In analysing the girl's behaviour, Tulving concludes that she is capable of mental time travel into the future.[3] He uses her as a model for a non-linguistic foresight test he calls *the Spoon test*, in which an animal must act analogously to carrying his own spoon to a different place for use at a different time. He sets out three requirements for such a test. The first is that the behaviour must not be instigated by, and must not satisfy, a present need or be governed by current physiological states. The second is that the behaviour should not be triggered, evoked, or guided by specific environmental stimuli that were present in the learning situation. Therefore, the location for the planning act must be different from the location containing for what is planned. The third is that the behaviour must satisfy a physical or psychological need that will arise in the future.

Tulving's proposal was inspired by the aforementioned unpublished criterion of Suddendorf (Suddendorf, 1994). Naturally, Suddendorf's and Busby's (2005) criterion was also based on these ideas. First of all,

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[3] Although the girl can anticipate, she apparently cannot tell apart mental constructs, like dreams, from the reality, as is crucial in planning. Tulving refrains from pointing out this particular cognitive deficiency of the poor girl.

they stress the importance that the behaviour must not be a result of associative learning, innate responses or coincidence. Furthermore, they propose that the animal should be able to perform anticipatory acts in different domains, to reveal flexibility, generativity and transferability.

The two-room paradigm, or *the rooms task* as it is also called, is a proposal with a basic design. It includes two rooms: one in which a basic need can be taken care of (e.g. thirst), and one in which this is not the case. (Instead this room might contain salty food items.) In a pre-training phase, the subject stays in the first room for a certain time before being allowed into the second room. Before moving over to the second room, the subject is offered a choice between different items none of which would reduce the drive state that arises in the second room (in this example, thirst). This procedure is repeated a number of times. In the testing phase, the choice that the subject is given before entering the second room should now include a familiar item that can address the drive state arising in the second room: e.g., a mug that can be filled with fluids before entering the room. The risk in the choice situation of any present drive for thirst is minimized because the subject has just had unlimited access to fluids.

Suddendorf and Coballis (2009) have recently refined and clarified the criterion by stating four explicit requirements. First, only single trials should be used, in order to avoid associative learning. Second, novel problems should be used, in order to preclude innate responses or effects from individual learning histories. Third, there should be a clear spatiotemporal separation between the future-directed action and its consequences, in order to avoid cuing and to ensure that long-time memory is playing a role. Fourth, the ability should be tested in different domains, in order to reflect flexibility and further reduce the risk of innate responses.

Osvath and Osvath proposed a somewhat different criterion (Osvath and Osvath, 2008 [Paper I]). It is similar to the others in taking care to exclude associatively learned and non-cognitive innate responses. Likewise it is careful to dissociate between current and future drives, and it requires the planning act to be performed at a different location from the execution. However, Osvath and Osvath's criterion focuses more on the function of foresight and on the executive functions of planning, which are related to the competition between (current and future) drive states. A planning act in one way or another involves disregarding a current psychological state in favour of a future one. Therefore a subject capable of planning with episodic foresight should be able to do this in a self-control setting: i.e., turn down an immediate reward in the expectation of a larger and better future reward. Normally in comparative self-control experiments, the immediate and the future reward differ only in quantity, whereas this criterion require different quality of the rewards as well – albeit both highly positive, to preclude the act being merely an inhibitory result. Moreover, the choice offered in the self-control situation should be between receiving the immediate reward directly and receiving only the means to reach the future reward (the "spoon" in Tulving's terminology), to ensure the expectation of the future reward while excluding sensory input from the future reward itself. This type of competition between drives differs from the competition implicit in the other proposed criteria and studies, as Osvath's and Osvath's criterion requires a consideration of two temporally separate outcomes: getting a reward of a certain type now, or getting a reward of another type later. The other proposed criteria, in their most motivationally taxing versions, seem to rely on the subject having an already reduced drive state of a particular sort, which the subject must then disregard in order to facilitate such a reduction again in the future. Osvath and Osvath argue that such a situation might involve episodic foresight only to a lesser degree, under the assumption that foresight evokes emotional states. When sated or quenched, it appears harder to evoke such states: i.e., the particular food desire or thirst. Foresight in such cases might have to rely heavily on semantic knowledge: e.g., "thirst occurs several times a day". In contrast in a self-control context, it seems clearer that the prospect evokes a state that competes with the state induced by the immediate reward. Osvath and Osvath's criterion also addresses the somewhat simplistic view expressed by the other proposed criteria, which seem to require no cueing to the future whatsoever. As the future does not yet exist, all cognition must take place in the present, to which the potential future must be brought. In order to consider the future in a way relevant for the subject, the future representation cannot contain haphazard or random information. Just as episodic memories are retrieved more or less appropriately to the current situation due to specific cues, so should foresights be formed. The mechanisms of such "pretrieval" are largely unknown, although the somewhat related research on prospective memories is making progress on how such memories might be evoked. The self-control criterion appears to be consistent with the cuing of an episodic foresight, so long as "the spoon" standing in an associatively learned or non-cognitive innate relation to the potential future is controlled for. The criterion of Osvath and Osvath is not explicitly described as a criterion for hominidea in the original text, however that is how it should be interpreted, for reasons returned to in section 2.6.5.

As might have been clear, all of the above criteria relate in one way or another to the aforementioned Bischof-Köhler hypothesis. The ability to foresee a motivational state seems indeed to be a consequence of the episodic system. What is not necessarily is that all episodic foresights include possible future affects. If a behaviour signals an anticipation of future motivational state, it likely reflects episodic cognition; on the other hand, if a future-oriented behaviour does *not* take forthcoming emotions into account, it might still be a result of episodic foresight. A falsification of the Bischof-Köhler hypothesis should therefore be viewed as a particularly strong sign of episodic foresight in a non-human animal, rather than a *sine qua non* for establishing such foresight in animals. It is theoretically possible that there exist episodic constructs in animals that are not phenomenologically rich enough to evoke emotions but are nevertheless sufficient to form sensorial simulations following from a current drive state.

2.5.2 Comparative studies on foresight

The studies conducted to date on animal foresight are extremely few. Those there are can be divided into corvid and primate studies. The first studies on apes, monkeys and crows were being done about the same time and relatively independently of each other, even if the order and content of the publications might suggest otherwise. This review will begin with the corvid studies, even though some primate studies appeared prior to them, in order to make a more comprehensible summary.

In two studies on scrub jays that were not directly aimed at investigating planning, researchers found seemingly advanced prospective feats: it appeared as though scrub jays could anticipate the future behaviour of others with respect to cache theft, and act optimally in response (Emery and Clayton, 2001; Dally et al, 2006). In 2007 Raby and colleagues specifically addressed the question of scrub jays' planning abilities (Raby et al 2007). The scrub jays were offered an opportunity to plan ahead by caching food. First the birds were introduced to two different rooms on alternate mornings. In one they were always given food; in the other, food was never available. After this training session, the scrub jays were given cacheable food in the evening. If they had any foresight, they would prefer to cache in the room where no breakfast would be served the next day. Indeed, the scrub jays did store significantly more food in the non-breakfast room.

To preclude the possibility that the birds merely had a propensity to cache in locations associated with previous hunger, Raby and colleagues conducted a second experiment in which the scrub jays were given breakfast in both rooms. However the food was of different sorts depending on location: always dog kibble in the one room and peanuts in the other. In the evening, if foreseeing the breakfast the next day, the birds should cache relatively more peanuts in the dog-kibble-for-breakfast room and *vice versa*. This is also what they did.

The same year another study on scrub jay planning was published (Correia et al, 2007). This study investigated whether the scrub jays could dissociate current from future motivational states in a caching context. This was achieved by pre-feeding the birds in two ways. Before the opportunity to cache, the scrub jays were pre-fed with one food type; just prior to the cache recovery, the birds were fed with another food type. If the scrub jays were able to dissociate current motivational states from future ones, then they should cache the food type they were pre-fed with prior to the caching, because when allowed to recover the caches they had already been pre-fed and sated by the other type. To cache the same type of food that the birds had just eaten would be at odds with how scrub jays normally behave, as they usually prefer to cache food types that they have not been recently eaten. The results were positive: the birds appeared to dissociate a current motivational state from a future one.

In 2006 two studies with rather different approaches to primate, ape and monkey foresight were published (Mucahy and Call, 2006; Naqshbandi and Roberts, 2006). The second published is of less concern for this thesis and is therefore presented first, followed by a more recent attempt with the same method on another primate species, before the more relevant great apes study by Mucahy and Call is reviewed.

Naqshbandi and Roberts compared squirrel monkeys (*Saimiri sciureus*) to rats (*Rattus norvegicus*) in what the authors presented as a test of the Bischof-Köhler hypothesis (Naqshbandi and Roberts, 2006). They based their study on a standard self-control paradigm where the animals were offered a choice between two amounts of the same type of food, one larger and on smaller. The food was thirst inducing, and prior to the selection procedure the subject's access to water was blocked. If the subject chose the smaller amount of food the water would be restored after a shorter interval (30 minutes) than if the animal selected the larger amount (180 minutes). This meant that selecting the larger amount would not only induce more thirst, but also prolong the waiting period for slaking the thirst. The hypothesis was that if the subjects were able to foresee the future state of thirst, it would reverse the normal urge to select the larger food reward. The monkeys reversed their preference, in contrast to the rats, who continued selecting the large reward.

The methods employed in the study were replicated in a study on rhesus monkeys (*Macaca mulatta*) (Paxton and Hampton, 2009). The authors found that the rhesus monkeys did *not* alter their preference to the smaller reward despite the prospect of increased thirst in the future. They then varied the setup by covering the food items with distinct opaque cups to assess whether the immediate sensory input from the food caused inhibition failure. The monkeys continued to select the larger reward. A third experiment controlled for whether the monkeys had difficulty inhibiting a larger reward despite the sensory variation, whether the resulting thirst was an acceptable cost for a larger reward, or whether the difference between the time intervals was not perceived. Both rewards were set to an equal size, and the longer interval was extended by an hour, to 180 minutes. The monkeys now selected at chance level. A fourth experiment tested whether the monkeys might have difficulty associating the amount of food to the water access delay. The short delay between the food and the drink was now set under a minute as opposed to the previous 15 minutes; the long delay remained the same at 180 minutes. In this experiment the monkeys did change their preference, in effect foreseeing a future motivational state as they were not thirsty when selecting. In a final experiment, the authors fed the monkeys with the thirst-inducing food just prior to their selection between two equal additional amounts of food, to ensure that the subjects were in the same motivational state during the selection as after (i.e., thirsty). The short interval between the selection and the provision of water was reset to 15 minutes. Regardless of their choice, the monkeys were again fed 15 minutes after the selection. In the short-interval case this was done just prior to the water access, so the water became at least as rewarding as in the fourth experiment. If the data in the first three experiments was a result of an inability to foresee future motivational states or the low reinforcement value of the water after the 15-minute delay, the monkey should select the smaller amount in this experiment. However, if the results were due to difficulties in learning the outcomes of the choices, the choices should be at chance level. The monkeys performed in the second manner. The authors concluded that rhesus monkeys indeed have the ability to foresee a future motivational state, albeit in highly limited temporal context; however, they are unable to learn sufficient associations as required in these experiments.

In relation to monkeys, it is worth mentioning that a preliminary study conducted on a squirrel monkey, with a method emulating the one used on chimpanzees and orangutans by Osvath and Osvath (2008 [Paper I]), indicated that the monkey could anticipate a future reward with a 60-minute delay; however, it could not exert the self-control needed to bypass an immediate reward in favour of the means to get to the delayed one (Osvath, unpublished data). The monkey required repeated training to be able to associate an artefact with a future reward, in contrast to the great apes who learned this in a single trial. (See below.)

The first published study attempting to explore planning for future motivational states in non-humans was conducted on orangutans and bonobos (Mucahy and Call, 2006). It consisted of four experiments. Prior to the first experiment, the subjects learned how to use a tool to obtain a reward from an apparatus. Then, in view of but without access to the apparatus, the ape was given the opportunity during five minutes to select a similar tool from among a collection of other, non-functional tools. (The assortment included two functional tools). After this interval the ape was ushered out from the room and into a waiting room. The subject had to remain there for one hour before it was allowed back into the first room. The apparatus was no longer blocked, and the subject was allowed to retrieve the reward if possessing the correct tool for the task. The apes selected and transported the suitable tool from the first room significantly above chance. They also returned with the correct tool to the apparatus room significantly more often than with inappropriate tools.

In a second experiment, the delay between the selection and the access to the reward was prolonged to fourteen hours, which included a night's sleep for the apes. The subjects performed at statistically significant levels in this experiment as well. A third experiment looked at whether the apes would perform at similar levels when the reward was not present during the tool selection opportunity. This experiment was aimed at controlling for whether the subjects in the previous experiment took the tools to reduce their current hunger. A new type of reward apparatus was used that now contained a liquid instead of the earlier solid reward. The subjects first learned how to use a new tool to obtain the new reward. Next the functional tool was placed together with three unsuitable ones. The apes were allowed to bring a tool with them after five minutes exposure. In this case the tool-selection room did not contain the future reward apparatus, as opposed to the preceding experiments. The subjects took the appropriate tools above chance level, and they returned with more functional tools than non-functional ones, although not at a statistically significance rate. A fourth experiment looked at whether the failure of the apparatus to materialise in the future would affect the tool selection results. This experiment was identical to the third experiment except that no reward apparatus was installed at the end. The apes were however given a reward if bringing back the previously appropriate tool. This experiment included different subjects from the third experiment, who were hence naïve to the function of the tool. In this experiment the subjects solved the task significantly less often than those in the third experiment, indicating that the relation between the tool and its future function was crucial to the preceding experiment. The authors concluded that great apes are indeed able to collect tools not needed currently but in the future.

In 2008 the second planning study on great apes was published, this time including chimpanzees and orangutans (Osvath and Osvath, 2008 [Paper I]). This study included four main experiments. Prior to the first experiment, the subjects was given a single training trial on extracting fruit soup from an apparatus using a straw. In the first experiment, the apes were presented with a tray holding four familiar objects, out of which one was the functional straw tool. They were allowed to select one item only. The selection was administered at a location different from, and out of sight of, the room where they previously had experienced the apparatus. The selected item then had to be kept by the ape in the day compound shared with other group members. After a 70-minute delay, the reward apparatus was installed, and the room was opened so the subject could retrieve the reward if the tool had been selected and retained. The selection of the appropriate tool was close to 100% and the retrieval percentage was high. The second experiment tested whether the apes could out-compete a current motivational state (the desire for a grape) in favour of the means (the straw tool) to get a future reward (the fruit soup). The experiment was identical to the first with the exception of the addition of a highly favoured grape on the selection tray. Subjects chose the straw significantly above chance. The third experiment controlled for whether the straw tool stood in an associatively learned relation to the future reward instead of being valued for its function. First the subjects were presented with a selection tray with identical content to the first experiment. When the ape had selected the functional tool (as expected) it was immediately offered a second selection tray with the same content as the second experiment i.e. including a grape. The rationale was that associative learning loads stimuli with intrinsic values: they become valuable in themselves regardless of e.g. their casual function. The straw tool, if learned associatively, would be valuable in itself and hence be selected for that and not because of its future function. That would be reflected in the second choice in the third experiment. If the tool had an intrinsic value, it would not matter if the ape was already in possession of one tool; if not, the most rational value-maximizing choice would be the grape. In 100% of the cases the apes selected the grape. The fourth experiment tested whether the subjects could select entirely novel tools that could potentially be used in the apparatus (see Figure 2). This would be evidence for the episodic system, which allows for such performances. The selection tray now consisted of three novel items and one familiar item. One of the novel items could be used as a functional tool in the future. All of these items were highly dissimilar in the eyes of a human. The apes selected the novel functional tools significantly above chance, and used a majority of them on the future-presented apparatus. The

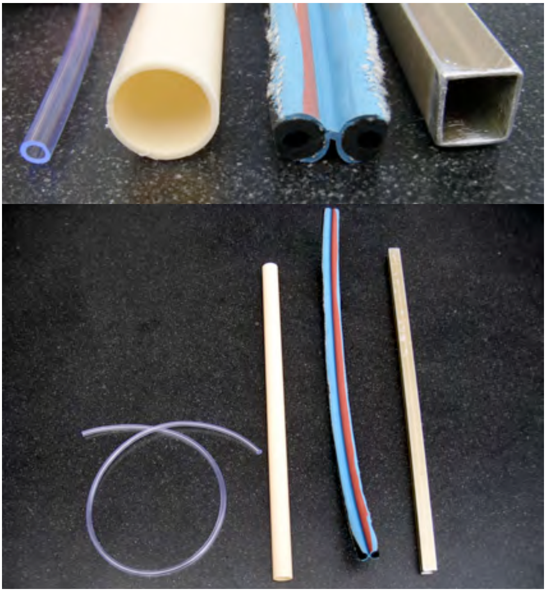

Figure 2. Three of the twelve novel tools used in the fourth experiment in Osvath and Osvath (2008). The tool at the left is the original tool used in the preceding three experiments. The other three tools were presented in different trials together with distracters. All of the tools in the pictures were selected, saved and later used correctly by all of the subjects.

authors concluded that great apes can plan for future motivational states, and that the most parsimonious explanation of the results is, indeed, episodic foresight.

Another study on planning abilities in great apes was published later the same year (Dufour and Sterck, 2008). The primary aim was to examine chimpanzee capabilities for planning future social episodes, in this case tasks where the subjects had to plan for future bartering with a human. The study consisted of five experiments, of which four were dedicated to barter planning, and one was a replication of parts of the aforementioned study by Mulcahy and Call (2006). In the first experiment, the chimpanzees were initially trained to exchange a distinct item for a food reward with a human. During the test phase, the subject gained access to a room containing this item as well as other objects also were associated with specific food rewards, however not in exchange situations. The ape was allowed to take any object during the ten minutes the room was open. One hour later the ape was brought into another room, where it had the opportunity to barter the previously learned item with a human. The apes did not succeed in bringing the correct item and exchanging it for a reward at any rate significantly above chance. The second experiment controlled for whether the resulting action reflected a specific preference either for an object in itself or for the food it was associated with, so that the chimpanzees selected the items they would prefer to use if they could. The results revealed that three out of the six individuals might indeed have done this; however, it did not explain at all the behaviour of the other three. The third experiment controlled for the possibility that the association between the exchange item and the reward was too weak to elicit a selection of the exchange item one hour prior to bartering. The exchange item was tested together with the other, non-exchange objects in an immediate setting. Four out of six subjects successfully associated the item with the exchange. In the fourth experiment, all other items than the exchange item were excluded from the selection room, to avoid any potential confounds they might have caused. The apes did not perform notably better in this simplified setting. The fifth experiment was a replication of the second of Mulcahy and Call's experiments (2006), in which the reward apparatus was not visible during the selection event. Similarly to the other study, the apes were successful in this experiment. The authors concluded that apes are able to plan for future tool tasks; however, they might not be able to plan for future social events. The authors cautioned that this conclusion might be premature, and the results could be the effect of experimental artefacts.

A study in progress indicates that it might indeed be premature to conclude that apes are incapable of planning for future bartering (Osvath and Persson, in progress). This study is aimed at partly replicating the study conducted by Dufour and Sterck, but within a more controlled setting. Instead of letting subjects select among items in a room over an extended time, they are forced to make a single choice from a selection tray offered by the experimenter. The idea is that the choice is the expression of a potential planning act, and this should be of primary interest rather than the success of the planning (although that is not unimportant). This arrangement makes it possible to record accurately the decision behaviour exhibited prior to the future exchange. So far the results strongly indicate that chimpanzees as well as orangutans are capable of planning for future exchange, with a higher success rate in the reward retrieval than the Dufour and Sterck's subjects managed.

In 2009 a study was published on the first documented, unambiguous observations of a non-human animal spontaneously planning for a future that includes a different motivational state from the present (Osvath, 2009a [Paper IVa and IVb]). This study aroused great excitement even outside the field, and was highlighted as one of the scientific breakthroughs of 2009 (e.g. Discover Magazine, Jan/Feb issue 2010). The study reported on a behaviour exhibited by a male chimpanzee over a ten-year period.

Dominant male chimpanzees often perform displays to confirm or uphold their rank, and this study focused on that behaviour. It is common in zoos for apes to throw items at onlookers, especially during dominance displays. The common effect of such demonstrations are that people move away in a hurry, which is similar to the behaviour that chimpanzees show when an individual engages in displays close to them.

The subject of this study began throwing stones at visitors shortly after he became the dominant individual in his group. However, the zoo staff always tries to keep the compound clean and empty of dangerous objects, resulting in very few loose stones immediately obtainable for a displaying chimpanzee. The subject in question solved the ammunition-shortage problem by gathering stones from the water moat surrounding the outdoor compound. He mainly did this early in the day, before visitors arrived. The gathered stones were placed, either in stacks or individually, on the shore facing the visitor’s side of the compound. Later in the day he would use the gathered stones in displays. The subject later extended his ammunition supplies by manufacturing concrete discs, which he obtained by exploiting the freeze-damaged concrete rock structures at the centre of the compound.

This behaviour is not only the first documented non-human behaviour of tool making for a foreseen need, but also one of a very few cases of tool making for other than food-related purposes. The subject appears to be completely calm during the gathering, manufacturing, and storing of the ammunition, as opposed to the highly agitated state of the display. As I suggested in the study, this contradicts the Bischof-Köhler hypothesis.

Also in 2009, a description of a pilot study was published on an orangutan’s ability to foresee a motivational state that had currently been reduced (Osvath, 2009b [Paper III]). This study presented the first preliminary evidence that great apes are capable of disregarding a sated state; this ability was previously shown in scrub jays as described above (Correia et al, 2007). First, experienced zookeepers established the male orangutan's point of satiation when drinking fruit soup. The established amount was then used as the reward in the experiment. The reward was placed in a paper apparatus outside the orangutan enclosure that could only be reached by a hose if used as a straw by the subject. This tool was inserted into the enclosure when the subject was not attending. It was later found by the subject and used spontaneously for extracting the reward. The reward reoccurred in a pseudo-randomized fashion three times a day outside one of the two enclosures that housed the orangutans. In order to get the subsequent rewards, the subject had to save and transport the tool after finishing each reward, as the subject did not have any information as to outside which enclosure the next reward would occur. In the successful trial, the ape saved and transported the tool continuously for three days, saving it overnight as well. The trial was aborted after this period due to the high calorie intake the successful behaviour resulted in. This study showed that great apes can overcome current satiation in favour of a future desire. It also showed the longest continuous planning action yet reported in great apes.

In 2007 a study was published on chimpanzee brain activity during wakeful rest (Rilling et al, 2007). This study did not specifically address the ability of episodic foresight in chimpanzees; however, it investigated the neural correlates in apes that appear to be essential for humans when planning episodically. This PET study revealed that chimpanzees in wakeful rest, similarly to humans, show high levels of brain activity within the so-called default-mode areas of the brain, including the medial prefrontal and medial parietal cortex. As described earlier, this state is highly associated with episodic cognition in humans. The chimpanzees differed from humans in that their ventromedial prefrontal cortex was more active, whereas they had lower activity in the left-sided cortical areas. The authors suggested that this indicates chimpanzees have a degree of self-projection, and that the differences arise from a higher emotional content as opposed to the linguistic and conceptual content to be found in humans.

2.5.3 Methodological and theoretical concerns

The comparative studies on foresight have not gone undisputed. On the contrary, they have elicited a fervent ongoing debate where the implications of the results have been questioned as well as defended (e.g. Suddendorf and Corballis, 2008; Clayton et al, 2008; Suddendorf et al, 2009; Osvath, accepted manuscript [Paper II]; Roberts and Feeney, 2009; Osvath et al, 2010 [Paper V]; Roberts and Feeney, 2010, Suddendorf, 2009).

The first broad critique of the comparative foresight studies – as conducted up until 2007 – was made by Suddendorf and Corballis (2008). They started by questioning the interpretations of the scrub jay study results. That study investigated whether the birds could anticipate a future motivational state after being sated through pre-feeding (Correia et al, 2007). Suddendorf and Corballis noted that the birds did not increase their caching of the desirable-in-future food, but instead decreased the caching of the non-desirable food. They argued that the scrub jays stopped caching food that would be available at recovery anyway. They said that this was not enough to show that the birds acted to secure the reduction of a future drive state. Instead, the birds learned not to store items with a low future value, which, they argued, is not the same as anticipating a future need. Suddendorf and Corballis continued by criticising the scrub jays study in which the birds were given the opportunity to plan for their breakfast (Raby et al, 2007). They argued that the birds could be using general heuristics to balance food sources between the locations instead of employing foresight, and hence were not actually doing planning. Next they criticized the primate studies. The study on squirrel monkeys who reversed their preferences when it became clear that the larger reward induced thirst (Naqshbandi and Roberts, 2006), did not, they said, qualify as planning for a future motivational state. Rather, the gradual reversal of preference over a number of trials could be explained as associative learning. They asked: If the monkey really had foresight, why it did not select the larger reward and adjust its water consumption, thus maximizing both food intake and slaked thirst? Finally, they dismissed Mulcahy and Call's study (2006) on great apes, simply by stating that it lacked appropriate controls to preclude associative learning

Clayton and colleagues (2008) responded to the critique of the two scrub jay studies. They argued that the critique of the study with the pre-fed birds oversimplified matters, in particular the motivational control of the food value incentives. In the absence of foresight, the decrease in general hunger state should lead to an overall decrease in caching. Non-foresighted behaviour in this context should result in equal (equally reduced) caching of the two food items. Clayton and colleagues argued that the critique of the "breakfast" experiment missed the point. Saying that the birds might use general heuristics to minimize food shortage at different locations does not take into consideration whatever cognition allows them to implement these alleged heuristics.

The next major critique of foresight studies was devoted entirely to the study by Osvath and Osvath (2008 [Paper I]). In an article entitled *How great is great ape foresight*, Suddendorf and colleagues (2009) criticize in detail multiple aspects of each of the four experiments in the study. They argued that the results could be explained by associative learning and immediate drive states, although they acknowledged that the final experiment using the novel tools would be hard to explain without granting the apes some level of foresight.

In response, Osvath (accepted manuscript [Paper II]) reiterated, with greater care, the aims and results of each study, emphasizing the interconnectedness of the experiments: one experiment controls for what the others do not. The conclusion was that Suddendorf and colleagues have profoundly misinterpreted the study, and the results in effect stand uncontested.

In 2009 Roberts and Feeney published a review of the field of comparative mental time travel (Roberts and Feeney, 2009). Their review was not merely descriptive. Although they found one scrub jay study (Raby et al, 2007) and two great ape studies (Osvath and Osvath, 2008; Osvath, 2009 [Paper I and Papers IVa & IVb]) to be outstanding research into possible future planning in animals, they still questioned the results. They argued that the results could reflect the employment of semantic memory instead of episodic foresight. The scrub jay data might only show a predisposition for caching food in locations where that particular food had not been encountered before. This predisposition, coupled with the semantic memory that a certain compartment did not contain a certain food, would be sufficient to account for their behaviour. Likewise the stone caching chimpanzee might have collected the stones based solely on the semantic memory of the periodic appearance of visitors, without foreseeing their appearance at a particular future time. Likewise the chimpanzees and the orangutans could have selected the functional tool only because they had a semantic memory of its function, and not because they anticipated the future reward. To remedy these shortcomings and to investigate whether the results truly reflected episodic foresight, they suggested that the animals should have to perform highly time-specific plans where more than one future option was included. For example, over a period of days the apes could be presented fruit soup (which they would need a straw to retrieve) at 12.10h and honey (which they would need a stick to retrieve) at 13.20h. Then at 11.00h on the test day, they should be asked to select between the straw and the stick. If the apes could foresee that the soup would appear prior to the honey, they would select the straw. This would then be proper evidence for mental time travel into the future.

Osvath, Raby and Clayton responded (Osvath el al, 2010 [Paper V]). Roberts and Feeney did not account for the crucial factors in the studies and did not refer to all of the central experiments. Moreover, they seemed to have a novel interpretation of semantic memory. However, the response focused instead on what the authors regarded as an essential misunderstanding. The decisive question in comparative mental time travel studies is the nature of the temporal representation: i.e. whether it is autonoetically constructed or not. Controlling for the ability to be highly time-specific in planning would not bring us any closer to the nature of the representation used than the studies already do. Indeed, in the sense that Roberts and Feeney talk of semantic memory, the positive result of their suggested study could as well be an indication of semantic knowledge that one event precedes another. The authors argued, following Friedman (1993), that episodic representations are rarely time specific, and the exact sequence of episodes does not seem to be encoded in the episodic system itself. Using the example of the stone caching chimpanzee, the authors pointed out that the studies adhered to currently accepted behavioural criteria for determining episodic foresight and that there were a clear dissociation between motivational states.

Roberts and Feeney did not leave this unanswered (Roberts and Feeney, 2010). They reiterated the importance of foreseeing the most proximate event in a sequence of events to any ability to mentally time travel. They gave the example of builders who do not plan to build the walls of a structure before the foundation is laid. In discussing the stockpiling chimpanzee, they did not refer to his dissociation between motivational states; instead, they focused on another crucial aspect of his behaviour: he did not store stones during the off-season when there are no visitors. They regarded this not as evidence of flexible anticipatory behaviour but as counterevidence, on the grounds that if the ape had foreseen the seasonal arrival of visitors, he would have had stockpiled a large store of stones in preparation for the spring opening.

There has been no opportunity to date for further counter-response. However, a few comments are appropriate. Roberts and Feeney appear uninformed about the comparative literature on sequential short-term planning, as there is ample evidence among a number of species for the ability to plan sequentially, even to formulate complex sequences (e.g. Döhl, 1970; Kuzcaj and Walker, 2006). The question of mental time travel revolves around the ability to foresee future motivational states. The case would already be settled for Roberts and Feeney if they were but aware of the sequential planning studies. Meanwhile their arguments about the stone-gathering chimpanzee could be questioned in a number of ways. It might however be enough to note that (as clearly mentioned in Osvath 2009) the chimpanzee compound is cleaned daily.

The latest critique by Suddendorf and Corballis (2009) repeats their previous arguments, while adding their response to the observations of the stone-gathering chimpanzee. They argue that systematic studies are needed to assess what caused the behaviour. They do not question that key components of the behaviour would normally signal planning for future motivational states; their concern is rather how these behaviours might initially have arisen. They note that the report is unique of its kind and that nothing like it has previously been reported either from the wild or from captivity. They do consider the possibility that the study might trigger an avalanche of similar reports from zoos and field stations.

2.6 More on the crux: subjective experiences

One of the most central and difficult questions in the comparative mental time travel debate is about subjective experience. Autonoetic consciousness implies not only subjective experience, but subjective experience detached from current sensory stimuli. There has been a strong reluctance in the fields of comparative psychology and cognition, as well as within traditional ethology, to hypothesise subjective experience as an explanation for behavioural results. More often than not this has been based on sound scientific considerations. However, I will argue that *sometimes* the most parsimonious explanation of the comparative foresight studies' results will be to postulate subjective experience as underlying the cognitive functions. This is particularly true for the hominidae lineage. Historically, vast amounts of ink have been devoted to the question of animal consciousness. (For contemporary discussions see Radner and Radner, 1996; Allen and Bekoff, 1997; Carruthers, 2005; Heyes, 2008). Obviously, the finer details of the arguments cannot be covered in the following sections. Instead, the reader might do well to compare the ideas presented here with that wider debate. The study of foresight in non-human animals might well have implications for that debate.

I will not deliver any conclusive arguments, and many sceptics will be unconvinced. Hopefully I can reveal some of the theoretical reasoning behind my empirical work. I am admittedly less sceptical of the arguments for the influence of subjective experience on foresight in hominidae than I am of those to the contrary. By "subjective experience", I mean the phenomenality, the “feeliness” of the experience: the "feel" of red, the "feel" of chocolate, or the "feel" of the screech of nails across a blackboard.

2.6.1 Cognitive functions and observables

A cognitive mechanism is usually defined by its function: what it does, how it is used (e.g., Shettleworth, 2010). There appears to be a clear-cut divide between two camps in the mental time travel debate, over what can reasonably be inferred from the observable functions addressed either by existing comparative studies or any future ones. This divide is somewhat different from the one already discussed, between those who argue that current studies support animal foresight and those who say they do not.

As previously noted, the research into episodic (or episodic-like) cognition in scrub jays makes reference only to what can be directly observed in behaviour. What is not observable is deemed irrelevant, as it presumed not to affect biological fitness. That is to say, whether the animal has subjective experience or not is irrelevant to establishing a cognitive mechanism unless it has an observable effect on behaviour. The researchers in these studies are not strictly opposed but remain sceptical to the possibility of establishing autonoetic consciousness from behaviours other than language. They are not alone in the belief that detecting subjective experience from non-linguistic behaviours is near to impossible. Rather, that view appears to be mainstream opinion within comparative psychology.

In the opposing camp there is an equal concern for the observable. Tulving, Suddendorf and colleagues, and I all argue that if autonoetic consciousness is indeed a defining factor of episodic cognition, then consciousness is *indirectly* observable in the function. That is, it would not be possible to perform certain behaviours without such consciousness: i.e., it is an integral part of the functions.

These differences of opinion boil down more or less to the question of what subjective experience is *for* – but also, it appears, to the question of which species are investigated.

2.6.2 Two problems of subjective experiences in comparative enquiries

There are two main reasons why subjective experience has been approached so cautiously in the fields of comparative and ethological research. The first need not be of much concern in this context. However, it deserves mentioned, because if the problem is eventually solved it will spill over to the understanding of subjective experience in general. Essentially the problem is that of not yet having a detailed model for what, in physiological, computational, or neurological terms, constitutes a subjective experience. At the moment there is no way to look into a brain and state conclusively whether a subjective experience is or is not taking place. If a chocolate-eating person reports having the unmistakable sensation of eating chocolate, the subjective experience *in itself* will not be detected by any current brain imaging technology. Looking into the brain of a chocolate eater is at present equivalent to monitoring the inner workings of a machine that discriminates between taste substances by chemical analysis; at best, we can perhaps identify the area of the brain used for chocolate detection. What we cannot yet see is the phenomenal sensation itself, in any scientifically useful sense. (We would probably not grant the taste-discriminating machine any such experiences.) The neurological or computational basis for subjective experience is yet to be discovered. This is a version of a longstanding discussion within philosophy of mind that David Chalmers has dubbed "the hard problem of consciousness" (1995).

The other problem is of more immediate relevance to the present discussion. What are subjective experiences *for*, both ultimately and proximately? That is, what fitness-raising benefits does a creature gain from having subjective experience, in comparison to a "mindless" cousin living in the same biological niche? What behaviours does it enable that cannot be performed without it? If subjective experience has evolved in response to selective environmental pressures, it must feed back on some fitness-raising behaviour that is in principle measurable empirically.

If the conclusions from the studies on human episodic cognition are correct and autonoetic consciousness is indeed a defining factor, then there is at least one identifiable benefit of subjective experience: a certain type of memory and foresight. Admittedly, this cannot be the reason for subjective experience to have evolved in the first place, as it must logically have existed *before* becoming detached from immediate sensorial input. Moreover, even if subjective experiences appear crucial in this type of foresight and memory, it is still not revealed more precisely why they are important. Nonetheless, autonoesis could be one example of an evolutionary benefit of subjective experience.

Some argue that subjective experience is nothing but a by-product of the evolution of other cognitive mechanisms with no fitness value of its own. Such a view is part of a position within philosophy of mind known as epiphenomenalism, in which mental states are regarded to one degree or another as causally inert, non-functional by-products of neurological processes.

2.6.3 Mixing epiphenomenalism with a subjective bat and the nature of science

The epiphenomenalist position is palpable in the research program on scrub jay mental time travel. Clayton and colleagues are explicit in why they do not consider subjective states in their research (Clayton et al, 2009, p 62): "…a subjective state of awareness is difficult to integrate with evolutionary processes of natural and sexual selection, which operate on behavioral attributes such as reproductive success and survival rather than on mental states." This is a clear presumption against subjective states affecting behaviour. However, the authors fail to produce any argument for this position.[4] Instead they take phenomenological talk to result from an anthropocentric way of thinking, and champion what they call an *ethologically based approach* meant to rely solely on objectively defined properties rather than any phenomenological ones.

Even if one accepts epiphenomenalism, this latter position might be hard to understand if one is not previously familiar with the ideas raised by Nagel's famous and widely debated article *What is it like to be a bat?* (Nagel, 1974). A brutal simplification of Nagel's position, relevant to this context, is that a particular subjective experience can ultimately only be available to the subject. If this is true, then of course there can be no objectively defined phenomenological properties. However, this is not the relevant empirical question within comparative foresight research, which is not concerned with *what* it is like to be an

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[4] Actually they might not be epiphenomenalists, at least not intentionally. Their position could just be a result of the species they are investigating, as will be returned to in Section 2.6.5.

animal exercising foresight. The important question is only *if* there is this somethingsness, the precise feel or subjective content of which is irrelevant. What matters is whether subjectiveness is an objectively identifiable property or entity that might facilitate cognitive functions. Science is about building models of reality, not about capturing it in all its true essence. There is no reason to assume that postulating subjective experience is different in principle from mapping the chemical composition of stars so far away that they could not physically be reached within the remaining lifetime of our species. Nor should it be any more impossible to specify than the workings of the smallest subatomic particles of the universe, too minute to be observed in any way by our senses, even with assistance. Both these examples come from well-respected fields of science relying on inferences from observable consequences back to the unobservable (or not directly observable) causes. The question of course is what observable consequences are we ready to accept as signs of subjective experience?

2.6.4 Is language a necessary or even a sufficient criterion?

The earlier described behavioural criteria for foresight proposed by Tulving, by Suddendorf, and by Osvath and Osvath are explicitly non-linguistic. They assume that there are distinct behavioural correlates for foresight. Because they are about *episodic* foresight, they contain the implicit claim that passing the tests would indicate autonoetic consciousness. Clayton and colleagues seem to believe that only a linguistic criterion could decide whether an animal has autonoetic consciousness. Tulving, Suddendorf, and Osvath can agree that a linguistic report would be strong evidence while allowing that a non-linguistic criterion might be sufficient. However, I doubt that a linguistic criterion would be sufficient in comparative studies.

It is worth pausing a moment to point out that a linguistic criterion might not be what we think it is. I would argue that the issue is not really about language. A linguistic report without any accompanying non-linguistic behaviours would not be sufficient. If a computer program were to tell us in voice or text that the computer on which it is running has autonoetic plans, we would reasonably doubt it. It would require a lot more to convince us. Consider this a version of the classic Turing test (Turing, 1950). We would require some further evidence from the machine: e.g., being able to answer a lot of tricky control questions. At the end of the day we would like to see it perform: to plan for futures in complex ways. One might argue that this is an extreme example and not relevant, as the computer is not an animal. However, such an argument would hint at underlying assumptions about animals, and about one species in particular: *Homo sapiens*. It might seem that we believe linguistic reports on autonoetic experiences from fellow humans beings because we relate to them and can compare the reports with our own previous experiences. We do not ask for more evidence, because the report comes from a human. This is a reasonable approach, pragmatically and sometimes scientifically. Would we just as readily believe a report on autonoetic experiences from a language-trained non-human animal? I suspect that we would require additional behavioural correlates. After all, when we do doubt linguistic reports by humans, it is often because the reports do not match the non-linguistic behaviour. To sum up: linguistic reports alone are not sufficient to determine subjective experience; non-linguistic behaviour is required as well.

The arguments above rely on the assumption that foresight implies autonoetic consciousness, and that a lack of such consciousness makes it impossible to plan for future motivational states. It would complicate things if a language-trained animal could plan with high complexity and at the same time report linguistically that the future and the past were "blank". Clayton and colleagues would then be right that language is necessary for determining autonoesis. After all, there is no logical necessity that planning for future motivational states on its own requires autonoesis.

The body of evidence on human foresight certainly makes a good case that human planning for future motivational states depends on something like autonoetic consciousness. But what about non-humans?

2.6.5 Phylogeny and foresight

The reluctance by Clayton and colleagues to postulate subjective experience in relation to foresight might partly be ascribed to their choice of subjects: corvid birds, separated from humans by approximately 600 million years of independent evolution (sharing a common ancestor about 300 million years ago). Similarities in cognitive functions for memory and foresight need not imply similarities on all levels of the neurocognitive system. Indeed, it is rather unlikely that this would be the case. So, it cannot be taken as given that autonoetic consciousness lies behind the memory and foresight abilities of Western scrub jays.

When similar traits occur in distantly related species, and these traits are not found in the common ancestor, then they are the result of homoplasic evolutionary processes. This simply means that something in the environment of the distantly related species, or rather their immediate ancestors, evoked similar selective pressures for evolving those traits. Simply put, similar pressures can produce similar traits in unrelated species.

Extremely little theoretical or empirical attention has been given to homoplasic evolution in cognitive traits. Two theoretical models have been suggested, one of which is a model for learning mechanisms: Papini suggested a four-level model to determine whether a learning trait appearing in two distantly related species is a result of homoplasy or homology (Papini, 2002). He distinguishes between the psychological, neurobiological, neurochemical and cell-molecular level. Without going into details, the *psychological level* corresponds roughly to cognitive functions. In terms of learning mechanisms, this level describes such concepts as S→S association. The *neurobiological level* corresponds to networks of neurons, the *neurochemical level* to synaptic workings, and the *cell-molecular level* to processes occurring inside neurons. In order for a trait to be homologous, it must be similar at all levels; otherwise, it is homoplasic (provided, minimally, that the psychological levels are similar).

Seed and colleagues have put forward a somewhat different model based on their review of potentially homoplasic cognitive traits in apes and corvids (Seed el al, 2009). The authors adopt the model developed by the vision researcher David Marr (1982), which distinguishes three levels of analysis in the psychological domain: *computation*; *representation and algorithm*; and *implementation*. These seem roughly to correspond with Papini's levels, but with a different emphasis. As with Papini's model, all levels must be the same in order for a trait to be homologous.

In light of this, it is highly unlikely that scrub jays have episodic cognition in the same sense as humans. The underlying systems producing this similar cognitive function should be different, because otherwise all species from the common ancestor of scrub jays and humans until today – including the dinosaurs – should have episodic cognition. This gives Clayton and colleagues some justification in using the term "episodic-like": it is not episodic in the same way as in our own species. However, Clayton and colleagues use "episodic-like" explicitly to denote cognition that need not involve autonoesis. This might not be the same thing as saying that the underlying systems differ.

Neither of these two models considers subjective experience as a possible facilitator of cognitive functions. Even though subjective experience could slot into some of the levels, its facilitating value is lost in any analysis relying on these models. It is at least logically possible that subjective experience -- more specifically, experience detached from immediate sensorial input -- can be produced by different underlying systems. Perhaps subjective experience, or at least a primordial version of it, whatever that might be, existed in the common ancestor. The sensory detachment might be a homoplasic trait. Without going into details, there have been some attempts, with positive results, to locate neuro-architecture that would facilitate subjective experience in birds (Edelman et al, 2005; Butler and Cotterill, 2006). The neuro-architecture for what Panksepp refers to as affective consciousness appears to be ubiquitous in mammals, suggesting an ancient origin (Panksepp, 2005). Thus, the possibility that scrub jays rely on a conscious system functionally similar to autonoesis is not far-fetched. However, it would most probably be the result of homoplasy. If this possibility would turn out to be true, it would pose a problem for how we define cognitive traits or functions: Should a system used for foresight and memory but utilizing an independently evolved conscious base be called episodic cognition? Or should that term only denote a system that it is equal to the human version on all levels of analysis, according to either of the two models described previously?

Regardless of how intriguing possibilities of independently evolved autonoesis might be, they are mere speculation at this stage. The caution exercised by Clayton and colleagues in analysing the data on scrub jays is well founded. The great ape studies present a much different picture: here, postulating autonoesis appears to be the parsimonious response.

The main reason for this is the phyologenetic proximity between humans and great apes. The results of the studies on foresight would be difficult to account for in other terms. If apes perform tasks that humans can only do with their episodic system, it would be at odds with current evolutionary theories not to assume the same episodic system. It appears as though humans with impaired episodic systems cannot plan in the manner that great apes clearly do in the foresight studies. If it truly is only these persons' episodic systems that are damaged or undeveloped, and apes lack equivalent episodic systems, then these persons should be able to use the same cognitive system the apes rely on in order to plan similarly. Moreover, if healthy humans were able to plan without using their episodic system, but with the same results as the apes, this would certainly have shown up in studies. One way to account for the facts would be that the common ancestor of great apes and humans evolved a system for foresight that mimics episodic foresight in function, but this system later regressed in the human lineage and was replaced by true episodic foresight. As regression of traits only occurs when they are not beneficial, this would mean that sometime during human evolution such foresight became superfluous, but then was quickly needed again. It is hard to imagine how such a seemingly complex system as the episodic system would have had time to evolve so quickly. Of course there is another possibility, that the apes possess an episodic system that does not include detached subjective experience but otherwise shares essentially the same architecture as the human version. When humans use their system, it evokes subjective experience as a more-or-less newly evolved by-product; when the system fails in humans, the subjective experience dependent on it goes “blank”, favouring a description of autonoesis as a defining factor in episodic cognition (incorrectly in this case). This would also imply that the previously described activity measured in chimpanzees’ brains at wakeful rest would not correspond to the subjective experience of humans during the same state; it would at best be a show for a blindsighted "inner eye", as the simulations might still prove valuable. But this is speculation unsupported by any evidence. So, to conclude: current evidence from the foresight studies on great apes, coupled with the existing data on humans, makes it parsimonious to hypothesise an episodic system for great apes that includes autonoetic consciousness as a defining factor.

2.6.6 The planning encyclopaedia: semantic foresight?

There have been competing suggestions on how complex planning could be accounted for, but with limited relevance to the great ape studies. These ideas arose in the domain of scrub jay research.

The performance by the scrub jays cannot easily be explained by associative learning or with non-cognitive innate propensities. At the same time, the reluctance to attribute episodic cognition, according to the current definition, or the associated autonoesis, requires an alternative explanation for the corvid behaviour. Raby and Clayton (2009) suggested s*emantic future thinking* as a plausible alternative. The same proposal had earlier been made by Suddendorf and Corballis (2007), but with few details. The argument is that with semantic prospection – planning entirely with factual knowledge (i.e., planning with the semantic memory system only, with no involvement whatsoever from any episodic system) – it should be possible to plan for anything that does not require imagining a future event.

Semantic future thinking is so far a purely theoretical construct without any supporting empirical data. However, the authors do give examples of how this hypothesised type of planning could work in non-humans. They suggest that a chimpanzee who prepares a stick for termite fishing might be using semantic prospection. The chimpanzee would need to have a concept of the stick as a potential probe, and it would need to be able to sequence all the actions correctly: searching for an appropriate stick, fashioning its end, and carrying it back to the termite mound. Perhaps more importantly, they consider the possibility from their own study (Raby et al, 2007) that the scrub jays', breakfast planning could have been an expression of semantic foresight. That is, the scrub jays might simply have known where to place the food with only a reference to a generalised future and without the particularities of episodic foresight. However, the same authors find it hard to explain the results of the study by Osvath and Osvath (2008 [Paper I]), without granting the chimpanzees and orangutans some more specific understanding of what the future might hold.

There are several problems with assuming a semantic prospective system as a parallel alternative to the episodic foresight system. The different natures of the semantic and episodic systems would seemingly not offer the possibility to turn the semantic system towards the future in a corresponding way to the episodic system. Semantic memories are not about the past in any direct sense; they are memories of facts, albeit ones that by logical necessity were acquired in the past. By contrast, episodic memories are about the past in a very direct sense. The same would be true of the potential futures of the episodic system. Whereas a fact is a fact, regardless of how it is used. There is no doubt that semantic memory is necessary for planning with episodic foresight, as such constructs rely heavily on knowledge of facts. Where it becomes problematic is assuming that semantic memories on their own can replace episodic constructs of the future in a planning action. Some planning probably does not require episodic abilities, while still relying on known facts, just as episodic planning does. However more is needed to do planning than just having the facts. It is this “more” that ought to be what non-episodic planning explains. To use the term "semantic" to describe planning in this way might therefore be confusing. Furthermore, one cannot help but wonder if the semantic system already existed in the common ancestor of birds and humans. There is a good chance that it did not, at least in the way it is currently defined, which would mean that such a system in birds would only be homoplasic to the one in humans – leading to the term "semantic-like". So perhaps semantic prospection is not an optimal way to evade the problems posed by the anthropocentric episodic system; solving one problem might just create another in the fascinating puzzle of homoplasic planning.

2.7 Language and foresight

Reading a thrilling book or listening to a great storyteller describing distant events would not be the same without the detached sensory experiences they evoke in you. The disappointment of watching a movie based on a favourite novel would not be so great if you did not have any prior mental images of what the characters and the places should look like. This relationship between language on the one hand and mental constructs resembling autonoesis on the other might be one of the reasons why language evolved in the first place. Language could also help explain why humans are capable of planning feats that have no counterpart elsewhere in nature. In the light of the studies presented in this thesis, it appears highly unlikely that humans alone have an episodic system. So, episodic cognition cannot by itself explain our exceptional planning abilities. It rather seems as if the tool of language, by which we address episodic constructs and share them with others, makes the difference. These ideas are once again speculative, and firm data to support them is lacking, but at the same time there are empirical and theoretical clues to support them.

It is interesting to note that already by the age of four to six years, humans appear to spend about half of their conversation time either on the past or the future (Szagun, 1978). The symbolic nature of language has the distinct benefit of making it possible to communicate things that are not currently present in time or space. Simply put, the symbols become stand-ins for the non-present. There is no obvious reason to evolve such communication in a species that does not have concepts about non-present things. More importantly language makes it possible to communicate about these private cognitive representations – the non-present things – and share them with others. It is plausible that language evolved as a response to the selective pressures to share such concepts with conspecifics. To establish such selective pressures, one must look for potentially fitness-raising behaviours that such sharing made possible in the hominin lineage. Before speculating on these, it is worth quoting Green and Donahue (2009) on what they regard as a key feature of receiving a story or narrative from another person (p 241): "Becoming immersed in story worlds, or transported into a narrative, might be considered a guided form of mental simulation. Rather than imagining one's own possible future or engaging in independent problem solving, a transported individual follows the tracks laid down by an author or a storyteller."

Green and Donahue are hinting at a lot of typically human concerns. Language makes it possible to convey past experiences from one individual to another effectively, and so to accumulate culture at a rate and with a quality of content above and beyond the ability of non-linguistic species. The question is, why would an individual share his episodic foresights and memories with someone else? Is it ultimately for the benefit of a complex culture? Great apes appear to have both episodic constructs and culture, but still do not share these constructs symbolically, at least not to the extent that it affects culture in the way it does in humans. Perhaps the first hominins had some lucky mutatations the other apes missed out on, which facilitated language evolution, to the benefit of culture. However, there are other possibilities. A certain type of cooperation between individuals appears to be one likely candidate for a typically human social behaviour that is not as apparent in the great apes. Without going into the details of comparative cooperation – a highly debated field in its own right – it is enough to note that humans on a regular basis cooperate toward shared future goals. Episodic foresight and a strong propensity for cooperation on their own would not be enough to make this possible; means of communication are also necessary, so that the episodic foresight of one individual may be aligned with that of another. Language does the trick.

What is needed to make cooperation toward future goals worthwhile, is a niche in which foraging depends heavily on social coordination and on resources that require planning for future motivational states. Gärdenfors and Osvath (2010 [Paper VI]) identified such a niche within the oldest known culture, the Oldowan. This African culture is at least 2.6 million years old, its existence having been established from the remains of flaked stone tools. The Oldowan was a hominin culture, probably founded either by the australopithecines or by the earliest *Homo*. It was characterised by hunting or scavenging (possibly both) that relied on sharp-edged stone tools. These tools are an example of a *curated technology*, meaning that they were transported long distances and probably also saved for future use at certain storage sites. The basic argument is that when an episodic-abilitied ape is using as a main foraging strategy a style of hunting/scavenging that is dependent on the rare resource of particular stones, then the need for cooperation about future goals becomes likely, and with it the need for communication toward achieving those goals. One should not allow the proximate features of modern language to confuse what one takes to be the ultimate reasons for the advent of language. Ontogeny does not recapitulate phylogeny. Modern human children develop a language prior to the developing episodic cognition. Patients with retro- and anterograde episodic amnesia do not seem to suffer from language production or comprehension problems. The systems might be, indeed appear to be, separate. The idea is that the selective pressures for language came from what was already happening in the mind, in terms of episodic cognition, together with requirements imposed by the environment

The above account is one possible story of how language came about. There is still the question of what language means today to human planning abilities. Very simply, a linguistically expressible concept has the dual property of being able to denote an episodic construct (as in the narrative examples) as well as a semantic memory (i.e., a fact). This duality, together with its shareability, make language an immensely effective tool for planning. Having perhaps arisen from foresight, language now takes planning and foresight to new levels.

Consider the famous statement by US President John F. Kennedy on September 12th, 1962: "We choose to go to the moon." What might be one of the most extensive plans ever made and executed so far in human history is summarized in seven words that take about three seconds to say. If the plan to go to the moon had needed to be represented in episodic foresights alone, it would have required extreme amounts of mental imagery on JFK's part. One could argue that picturing people on the moon in episodic foresight would have the same status, but it would not. Without the coupling to language qualities, it would just be an image of particular people on the moon, and not a stand-in for the plan to get there. Beyond this, the plan to go to the moon was not one man's plan; arguably it required thousands upon thousands of sub-plans in just as many individuals, all of which needed to be coordinated to a level of detail only obtainable through language.

The somewhat predictable answer for what makes human planning special appears to be: language.

2.8 Concluding remarks

The field of comparative episodic foresight is still in its infancy. A large amount of research is needed before there will be any significant understanding of the mechanisms and evolution of this ability. More studies are needed that address the yes/no question of autonoetic consciousness. At the same time a lot more effort must be made to increase the resolution at which the different mechanisms at work in the studied species can be described. More species should be studied, beginning with the closest relatives to the great apes. From the perspective of homoplasy, more corvids should be tested, perhaps expanding beyond the domain of caching behaviour. More direct comparisons between human children, in their development of their episodic system, and the episodic cognition of non-human animals would be fruitful. Comparisons of patients with retro- and anterograde episodic amnesia with non-human animals on equivalent tasks could likewise be fruitful. The hypothesised function of episodic foresight in planning – imagining futures to evoke current emotions – should be further investigated. This would require a translation of studies on human affective forecasting into non-human settings. Last but not least, the role of language should be systematically considered in comparative studies, which would then need to include humans but also, ideally, language-trained non-humans.

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Paper I

Undoubtedly a ('voluntary') shifting of the attention from so strong a momentary interest, merely on account of the expectation of a greater general advantage later, would be a very notable achievement.

W. Köhler (*The Mentality of Apes, 1925*)

Chimpanzee (*Pan troglodytes*) and orangutan (*Pongo abelii*) forethought: self-control and pre-experience in the face of future tool use

Mathias Osvath and Helena Osvath

Abstract Planning for future needs has traditionally been considered to be restricted to human cognition. Although recent studies on great ape and corvid cognition challenge this belief, the phylogenesis of human planning remains largely unknown. The complex skill for future planning has not yet been satisfactorily established in any other extant primate species than our own. In humans, planning for future needs rely heavily on two overarching capacities, both of which lie at the heart of our cognition: self-control, often defined as the suppression of immediate drives in favor of delayed rewards, and mental time travel, which could be described as a detached mental experience of a past or future event. Future planning is linked to additional high complexity cognition such as metacognition and a consciousness usually not attributed to animals. In a series of four experiments based on tool use, we demonstrate that chimpanzees (*Pan troglodytes*) and orangutans (*Pongo abelii*) override immediate drives in favor of future needs, and they do not merely rely on associative learning or semantic prospection when confronted with a planning task. These results suggest that great apes engage in planning for the future by out competing current drives and mentally pre-experiencing an upcoming event. This suggests that the advanced mental capacities utilized in human future planning are shared by phylogenetically more ancient species than previously believed.

Keywords Planning · Mental time travel · Self-control · Bischof–Köhler-hypothesis · Animal consciousness

Introduction

It is commonly argued that the skill to plan for future needs is exclusive to humans (e.g., Atance and O'Neill 2001, 2005; Gilbert and Wilson 2007; Gulz 1991; Köhler 1921, 1925; Noble and Davidson 1996; Premack 2007; Roberts 2002, 2006; Suddendorf and Busby 2005, Suddendorf and Corballis 1997, 2007; Tulving 2005). The assertion that non-humans are unable to use flexible cognitive prospection beyond the present need is dubbed the Bischof–Köhler hypothesis (Suddendorf and Corballis 1997). Undoubtedly, such future need planning plays a decisive role in human life and society, at the same time it is tremendously difficult to observe the behaviors of non-humans. Observational reports on future planning in animals barely exists, and the few that do (Boesch and Boesch-Acherman 2000; Byrne 1995; de Waal 1982), fail to give unequivocal accounts as they represent single occasions or do not rule out alternative interpretations. Surprisingly, only modest experimental efforts have been made to settle the question whether this pivotal skill is unique to humans. This study explores some central aspects of forethought in great apes, and addresses the Bischof–Köhler hypothesis.

Even though planning always concerns the future, not all future oriented behaviors are the result of planning. The flexible cognition required for planning is not necessary in a range of common anticipatory activities such as nesting, hibernation, migration or food hoarding. In many species, such behaviors appear to rely on comparably rigid and innate mechanisms.

Planning skills could be divided into levels of complexity and might be theoretically approached from different angles. An important distinction is between planning for present needs and planning for future needs (e.g., Byrne 1995; Gulz 1991). Many animals seem to solve sequential problems in order to fulfill present drives, thus making planning for immediate needs a rather spread activity in nature. The skill for immediate need planning is in itself a conglomerate of cognitive sub-mechanisms. Even if different species share the capacity for immediate planning, they might still differ from each other in the complexity of the skill. The topic of this study, however, is the other aspect of planning.

In humans, planning for future needs involves two broad and fundamental cognitive capacities (e.g., Atance and O'Neill 2005; Szpunar etal. 2007), both essential in our cognition. The first is an inhibitory capacity that may be summarized as the exercise of self-control, often defined as the suppression of immediate drives in favor of delayed rewards (e.g., Ainslie 1974; Mischel et al. 1989). The second is a capacity to construct mental experiences of potential events, something that could be expressed as a projection of the self into possible future events, regularly referred to as mental time travel (e.g., Suddendorf and Busby 2005; Suddendorf and Corballis 1997, 2007; Tulving 2005). In humans, both these abilities develop fairly late and around the same age, at about 3–5years (Atance and O'Neill 2005; Suddendorf and Busby 2005). Self-control and mental time travel are vital concepts in the understanding and testing of the Bischof–Köhler hypothesis, as shall be dealt with in detail further.

Self-control is typically measured by letting subjects choose between smaller immediate rewards and larger delayed rewards (e.g., Tobin and Logue 1994). This is as an operationalization of a broad inhibitory ability involved in an array of cognitive operations. Without self-control, an immediate reward evokes a motivation stronger than the one for obtaining a larger future reward, and as a consequence any plans for future needs cannot govern the behavior at that time. Self-control is studied in a range of paradigms, from animal cognition to economics, and is recognized as a demanding ability profoundly integrated in human cognition. Levels of self-control in humans correlate strongly with a variety of complex cognitive abilities, and predict individual success in domains as diverse as interpersonal skills, psychopathology and academic achievement (Mischel et al. 1989; Tangney et al. 2004; Carlson and Moses 2001; Duckworth and Seligman 2005). The human capacity is often considered unparalleled and allows us to wait for hours, or even years, to obtain a reward (e.g., Fredrick et al. 2002). In contrast, the self-control displayed by animals is characteristically restricted to extremely short delays between the smaller and the larger reward (Ramseyer etal. 2006; Roberts 2002, 2006; Stevens etal. 2005). The impulsivity of animals is one of the main reasons for the assumption that they are mentally stuck in the present time (Köhler 1921; Roberts 2002, 2006). Nevertheless, some studies show that chimpanzees have well-developed self-control (Beran et al. 1999; Beran and Evans 2006; Evans and Beran 2007; Rosati et al. 2007). One study even suggests that chimpanzees are comparable to humans in self-control tasks involving food rewards (Rosati et al. 2007). This indicates that great apes should be suitable for complex planning skill investigations. It is worth noting that, as a testament to the cognitive tightrope act behind self-controlled behavior, humans regularly fail to override immediate drive states to obtain delayed gratification (e.g., Ainslie 2001).

Mental time travel is thought by many to be exclusive to human thinking (e.g., Gilbert and Wilson 2007; Suddendorf and Busby 2005; Suddendorf and Corballis 1997, 2007; Tulving 2005;). The ability is closely connected to the concept of episodic memories, first described by Tulving (1972). Episodic memories enable us to recall something as opposed to just know something, which is semantic memory. For instance, we know that most boats float on water (semantic memory) but we can actually recall occasions when we personally have taken boat rides or have seen floating boats (episodic memory). This recall constitutes the retrospective part of mental time travel. The forward part, projecting into possible futures, is most likely based on the same cognitive system as episodic memories, and hence involves a form of mental life-like experience as opposed to a mere knowledge about upcoming events. The system constructs and reconstructs events mentally rather than purely constituting a memory structure (e.g., Atance and O'Neill 2001, 2005; Suddendorf and Busby 2005; Suddendorf and Corballis 1997, 2007; Tulving 2005). Accumulated neurological data confirm that prospection and retrospection, and perhaps even theory of mind, rely on the same core brain network (for review see Buckner and Carroll 2007). The defining character of an episodic system in use is the experience of a first person view of re- or pre-experienced events. In humans, envisioning a non-present situation is the key feature of mental time travel (e.g., Gilbert and Wilson 2007; Szpunar etal. 2007). Naturally, other modalities than vision also contribute to this mental re- or pre-experience. Such travels, with their first person perspectives, involve a certain form of self-consciousness allegedly limited to human cognition (Tulving 2005; Gardiner 2002; Macphail 1998).

In this context, it must be noted that a prospective system analogous to the semantic memory system of declarative general knowledge has been suggested (Suddendorf and Corballis 2007). This semantic prospection system allows its owner to voluntarily apply knowledge acquired in one situation onto another. Semantic prospection is rule based and thereby only sensitive to regularities of potential future events, as opposed to the episodic system that by pre-experience pick out particularities of the possible future events.

Behavioral experiments suggesting episodic-like memories in, for example, corvids and primates (e.g., Clayton and Dickinson 1998, 1999; Schwartz etal. 2005) are partly disputed, mainly because the studies are claimed to be inadequate in ruling out associative learning or species-specific behaviors (Suddendorf and Corballis 2007; Tulving 2005; Roberts 2002, 2006). The question about the related skill of episodic prospection in non-humans will be dealt with further. However, it should be mentioned that the specific brain state at wakeful rest, that is strongly linked to mental self-projection in humans (e.g., Christoff et al. 2004; Andreasen et al. 1995; Ingvar 1979), has currently been reported to have a counterpart in chimpanzees (Rilling et al. 2007).

Behavioral criteria of this study

Behavioral criteria are obviously the *sine qua non* of establishing prospective cognition in non-humans (e.g., Suddendorf and Corballis 2007; Suddendorf and Busby 2005; Tulving 2005). Consequently a detailed discussion must be devoted to the criteria that are specifically set and adhered to in this study. An examination of the meaning of the Bischof–Köhler hypothesis reveals the intertwining of self-control and episodic prospection and their central role in testing the hypothesis. The latest version of the Bischof-Köhler hypothesis states: "[…] only humans can flexibly anticipate their own future mental states of need and act now to secure them" (Suddendorf and Corballis 2008). The expression "flexibly anticipate" relates to cognitive operations that represent the particularities of a future event, which implies episodic pre-experiencing, and hence excludes innate mechanisms, associative learning and apparently even semantic prospection. The phrase "mental states of need" is somewhat more intricate to construe, particularly given the much-debated status of these concepts dating back to, at least, the seminal work of Maslow (1943). However, "need" could in this context simply be viewed, somewhat circularly, as something that is expressed as a motivation to reduce the need, and not necessarily as a life-supporting biological need. This interpretation assumes that "mental states" is equivalent to a drive state. A typical example of such a drive state would be a desire of some sort. The latter part of the hypothesis pinpoints the key act of planning execution, describing the ability to act in the present in order to secure the anticipated need. The motivation for future planning must be stronger than the motivation to act for the present situation; a well-developed inhibitory capacity is required.

The adoption of the self-control paradigm in the investigation of planning skills in non-humans proves fruitful for several reasons. This was appreciated early on in the field when Wolfgang Köhler pointed out the importance, in the context of chimpanzee forethought, of finding behaviors where an immediate interest is disregarded in favor of a future interest (Köhler 1921). The merits of the self-control paradigm are immediately palpable in relation to the end section of the Bischof–Köhler hypothesis. A specifically designed self-control setting creates a decisive test of the ability to act in the present to ensure the satisfaction of a future need. To decline the immediate satisfaction of one drive in favor of a future oriented one is arguably a most taxing planning situation. The rejection not only requires patience, but also tolerance against the discomfort of not getting the immediate satisfaction.

Less obvious, perhaps, is the methodological strength of the self-control setting when contrasted with what appears to be a prevailing experimental approach of the field. A common example of prospective mental time travel is the ability to foresee a drive that is currently satiated (e.g., Suddendorf and Corballis 2007; Correia etal. 2007). Experiments based on this view ensure that the drive state of the need that is planned for is satiated during the prospective actions. However, anticipation under such circumstances could be served by semantic prospection rather than by an episodic process. Besides being introspectively intuitive, neurological data not only show that satiation neutralizes the prior positive affective value of the stimuli (e.g., O'Doherty et al. 2000), but also that over-satiation leads to aversion (e.g., Small et al. 2001). How a pre-experience of, for example, thirst when currently quenched would be manifested is not readily grasped. Arguably, semantic prospection, and not necessarily a first person pre-experience of a forthcoming dehydration, produces the adequate incentive to fill up the water bottle when a thirst is slaked. Note that this is not equivalent with an a priori impossibility of the use of episodic prospection in any of such planning tasks, but rather it means that an anticipatory behavior is executed when satiated is not a decisive criterion for episodic forethought. In the search for behavioral criteria, an indisputable sign of episodic pre-experience appears to be unattainable. However, experiments based on a self-control design, increases the likelihood of measuring the outcome of a struggle between drive states related to the present and the future. A self-control experiment differs from a satiation experiment in that drive states are induced and present instead of reduced and absent. Having contesting drive states offers an opportunity of the future oriented one being related to a pre-experience, as opposed to the satiation context where pre-experience is a less probable process. If pre-experience of some aspects of the possible future evokes the motivation to act towards this future, then this poses a case of first person episodic relation to the upcoming event.

Self-control experiments aimed to elucidate planning skills need some specific design requirements. These must be scrutinized in order to expound the behavioral criteria pursued in this study. First of all, to ensure that the self-control setting offers competition between *different* desires, the stimuli in the choice situation must represent different kinds of rewards. The immediate reward must be qualitatively distinct from the future one; otherwise the outcome of the choice would only be an expression of inhibitory strength and not of the ability to distinguish the future oriented drive from the present oriented one. And of course, both rewards must be highly valued but different in quantity, with the lesser amount in the immediate situation.

Secondly, it is pivotal that the cuing occurring in the self-control setting is thoroughly controlled; otherwise associative learning or immediate need planning cannot be precluded. To understand the role of cuing in planning, it should first be realized that cognition resulting in prospective behavior is cued, externally or internally, in the current situation, otherwise it would not be the result of deliberate planning, but of chance-like mental processes (haphazardly popping up in the head). On the other hand, to qualify as planning for the future, the prospective behavior must not be instigated by a current drive state or some present stimuli that might stand in an associatively learned relation to the future event (e.g., Tulving 2005). This distinction between cued and learned relations can be clarified by highlighting the difference between association and associative learning. Association, as in associating something to something else, is an everyday term that potentially includes a wide variety of cognitive mechanisms involved in cuing processes. Associative learning, on the other hand, is a term describing learning mechanisms characterized by an arbitrary connection between stimulus and reward, a link that is, so to speak, blindly learned through reinforcement. Another essential and related point is tied to the status of the drive state in the planning situation. Planning takes place in the present and is always governed by a motivation. It is the way in which this motivation is evoked that should make the difference between being an immediate and a future planner.

A cue to a future event might eventually result in a drive state, for example a craving, that in turn evokes a motivation to plan, however, it is not the drive state *per se* that evokes the prospection, rather it is the other way around. This distinction is crucial: creatures unable to plan for future drives should be incapable of representing the future in a way that evokes a drive related to it. In fact, the emotional information received from a pre-experience of a potential future seems to constitute one of the key functions of an episodic prospective system (e.g., Gilbert and Wilson 2007; Ainslie 2007; Atance and Meltzoff 2007). Given the above distinctions, it is recognized that the motivation for planning for future needs not only might, but must, be triggered, and that this trigger may very well be a current drive state connected to the future event as long as this is a result of some form of forethought. This leads to the other imperative requirement for a self-control setting designed to study planning abilities: the stimuli related to the future event must be controlled for not having an associatively learned connection to the upcoming reward. If there does not exist an associatively learned link, then the potential cuing should be compatible with true planning for future needs.

As mentioned, there is probably not a single test providing both the necessary and sufficient elements to falsify the Bischof–Köhler hypothesis. A properly designed and well-controlled self-control setting, most certainly evokes a drive towards the stimulus of the present reward, and it is highly likely that the future oriented stimulus also induces a drive that offers competition. However, it is possible that only the future related drive is a motivation to plan, instigated by a rule-based knowledge of an upcoming event instead by a pre-experience (given that a motivation to plan is not viewed as a pre-experience). An interesting consequence is that positive results from such experiments would clearly indicate planning for future needs, without falsifying the Bischof–Köhler hypothesis.

Further investigations of the episodic content should be related to the term “flexibility” in the Bischof–Köhler hypothesis. An operationalizable distinction between episodic and semantic prospection is that the former deals with the particularities of the upcoming event, whereas the latter is only concerned with regularities (Suddendorf and Corballis 2007). An intuitive test would be to create future situations with each having a unique character, and then control for whether the subjects take into account the exclusive features of each future situation when planning. However this is a non-viable experimental construction, offering a low degree of control. The difficulties are numerous, but the most severe would be to inform non-linguistic subject in a controlled fashion about the unique upcoming event, and further to ensure that this information has been interpreted in the intended way. However, even if episodic prospection proves its strength in relation to unique events, it could still be tested with repeated future events with the same re-occurring content. Instead of manipulating the future events, the current situation in which the planning takes place could be altered so that it relates to the particularities of the future event, for example, letting subjects select between functional and non-functional novel tools that could potentially be used on a familiar future problem, where the potential functionality must be mentally compared with the particularities of the future situation. In other words, an investigation, in the planning situation, of the sensitivity to unique particularities linked to features of the upcoming event, would provide robust insights into the ability to foresee the particularities of a future episode.

Some recent studies on future oriented cognition in corvids and primates challenge the Bischof–Köhler-hypothesis to some extent. Two studies on Western scrub-jays (*Aphelocoma californica*) show that these birds adapt present actions to a future need without reference to a current drive state (Correia et al. 2007; Raby et al. 2007). These studies are based on the satiation-setting: controlling for the lack of the specific drive state that the anticipatory action is aimed at. The results indicate a skill for planning for future needs. However, the planning behaviors of the scrub-jays have been proposed to be specific adaptations to the caching context rather than constituting a flexible skill of the kind seen in humans (Gilbert and Wilson 2007; Premack 2007; Suddendorf and Corballis 2007). True or not, the prospective abilities of corvids must indeed differ vastly in phylogenesis from that of humans due to the considerable distance to our last common ancestor (e.g., Emery 2006). This makes the data highly interesting, as they provide a good example of how complex cognitive traits might result from convergent evolution in distantly related species.

Nonetheless, to gain deeper understanding of the particular evolution of the human planning ability, studies of primates are necessary. It has been revealed that bonobos (*Pan paniscus*) and orangutans (*Pongo pygmaeus*) can select and save a tool for later use (Mulcahy and Call 2006), and that future states of thirst may affect present food choices in squirrel monkeys (*Saimiri sciureus*) (Naqshbandi and Roberts 2006). These studies remain controversial, as the drive states of the subjects are not controlled for (Correia et al. 2007; Raby et al. 2007; Shettleworth 2007; Suddendorf 2006; Suddendorf and Corballis 2007) and associative learning is not sufficiently excluded as an explanation of the results (Correia et al. 2007; Raby et al. 2007; Shettleworth 2007; Suddendorf and Corballis 2007). The study of Mulcahy and Call (2006) showed that great apes are capable of saving tools needed in a distant future. However, a control for the motivational state of the subjects was not included in these experiments (as opposed to the studies of the scrub jays). It has been suggested that the subjects could potentially experience a desire for the reward throughout the experiment (Suddendorf 2006; Suddendorf and Corballis 2007). Therefore it is not considered clear whether the apes only anticipated the future need for the tool or if they also foresaw their future motivational state. Furthermore, some argue that it is not possible to exclude associative learning because the same tools rewarded the subjects throughout the experiment (Suddendorf and Corballis 2007).

Due to these considerations, it is still an open question whether primates other than humans possess the multicomponent skill for future planning. Consequently, the evolutionary history of one of our most significant cognitive skills is largely still earthed. To begin to resolve the question whether great apes are cognitively capable of planning for future states in a way similar to that of humans, it must be shown that they can go beyond the satisfaction of immediate drives, and it must be demonstrated that subjects do not merely employ associative learning or semantic prospection instead of episodic prospection in a planning task (Correia et al. 2007; Gilbert and Wilson 2007; Gulz 1991; Köhler 1921; Raby et al. 2007; Shettleworth 2007; Suddendorf 2006; Suddendorf and Busby 2005; Suddendorf and Corballis 1997, 2007; Tulving 2005).

The following series of experiments adhere to the afore described behavioral critera, and thereby not only addresses the methodological concerns raised towards the previous planning study conducted on great apes (Mulcahy and Call 2006), but also extends the investigations further. To properly tackle some of the intriguing issues of planning skills in non-human primates, we engaged two chimpanzees (Linda and Maria Magdalena) and one orangutan (Naong) in a series of experiments. The aim was to give an answer to: whether great apes meet the above-mentioned cognitive requirements in planning tasks; whether they are capable of out-competing a current drive in favor of a highly delayed reward; and whether they are able to act towards a future by pre-experiencing it mentally rather than relying on associative learning or semantic rule following. The study included four experiments, divided into a baseline, a selfcontrol test, an association control and pre-experience test.

Experiment 1: baseline

This experiment tested the apes' selection of objects in a choice situation, presenting an opportunity to get hold of a tool leading to a delayed reward at a location not visible from the selection site. The experiment was divided into two phases. The first phase included tool use training and a setting that was intended to inform the subjects about the reoccurrence of the reward. The second phase was the actual testing. Before the experiment was initiated, a control was conducted on the experimental procedure and on parts of the key materials.

Methods

Subjects

Two chimpanzees and one orangutan housed at Lund University Primate Research Station, Furuvik Zoo (Sweden) participated in the main experiment. The two female chimpanzees, Linda and Maria Magdalena, were 22 and 6 years old, respectively. The male orangutan Naong was 12 years old. Linda, who was wild-caught in Liberia, was partially hand raised, while the other chimpanzee and the orangutan were mother raised in captivity. The chimpanzee subjects shared their enclosure with three other chimpanzees. One of these was a male at 28 years of age, in alpha position. The other two were females, one adult at 24 years of age and one infant (of Linda) at the age of 2. The orangutan shared the enclosure with a 20-year-old female. The two adult chimpanzees and the female orangutan served as control subjects in the control for biases, in the materials or the selection procedure in Experiments 1 and 4, but did not take any further part in the study.

All subjects were experimentally naïve when this study started. The subjects lived in their social groups and in their everyday indoor and outdoor enclosures during the experiment. They were not deprived of water or food. Water was accessible *ad libitum* in the enclosures.

Materials

A wooden box (19 x 15 x 36 cm) contained a transparent plastic bottle, accessible through a hole (2.5 cm in diameter) on top of the box. At the front of the box, a 15 cm high Plexiglas panel offered a view of the contents. The reward was half a liter of a highly favored fruit soup. To obtain the reward, a soft and transparent plastic hose was needed (70 cm in length and 4 mm in diameter). It was used as a straw to suck the soup up. The hose was placed on a wooden tray (75 x 45 cm), from which the subjects could select between this functional tool and three other distracter objects. The distracter objects were objects commonly used by the subjects in different enrichment activities and thus possibly associated with previous rewards. The distracters were a rope, a bamboo stick and a heavily knotted sling.

Procedure, design and control

The training phase was designed to let the subjects learn how to use the tool to obtain the large liquid reward, and to inform them about the reoccurrence of this reward. At the same time, the opportunity for associative learning was kept at a minimum by not allowing repeated training, with short intervals between the tool and the reward. A keeper demonstrated the plastic hose and its function by sucking fruit soup from the apparatus while a subject was observing from close range. Then the hose was extracted from the apparatus and handed to the subject. Subsequently, all three subjects spontaneously reinserted the hose into the apparatus and obtained the reward. The tool use training was restricted to this single trial. This was also the only occasion during the entire experiment series when subjects were immediately rewarded by acquiring the tool. Later, the baited apparatus was installed in a reward room to which the subjects were granted access without possessing any tools. This was done to create a possible incentive for possessing a functional tool in the future. This procedure was repeated twice in a day. The day after having experienced these reoccurrences, subjects were presented with the tray containing the four objects out of which one, the hose, was functional for obtaining the reward. Subjects were only permitted to select one of the objects. The training selection was made when the apparatus was visible but unattainable in the reward room. Subjects were not allowed into the reward room until 1 h had passed after their selection. All subjects selected the functional tool in the first training trial. This was the second time they ever saw the tool.

In the actual experimental task, the subjects were individually called inside a selection room, from where the reward room was not visible. A trial started, with the ape being offered to select one of the four objects from the tray. The tray was placed out of reach but within sight for approximately 4 s. Then it was slid towards the subject. To minimize potential cuing, the experimenter never looked at the objects before the ape made the selection, and fixed his or her gaze at a point slightly above and behind the head of the subject. As soon as the subjects selected an object by either touching it or its immediate area, the tray was removed to avoid attempts to acquire more than one object. The objects were located approximately 10 cm from each other resulting in unambiguous choices. The position of the objects was pseudo-randomized between trials. After the selection procedure, the subjects returned to the daily enclosure with the selected object. This enclosure was shared by other group members, something that forced subjects to keep track of and sometimes defend their tool (this set up was of importance for Experiments 2 and 3, as will be returned to). Seventy minutes later the apparatus was installed and the subject gained access to the reward room. A trial ended as soon as the subjects obtained the reward, or when 5 min had passed. After the reward was finished, the tool was taken away from the subject. Then the subjects were urged to return to the enclosure from where they could observe the immediate removal of the apparatus. Prior to every trial, subjects had the opportunity to observe that no apparatus was installed in the reward room before they were called inside the selection room, since the bars dividing the daily enclosure and the reward room offered full view. Fourteen trials were performed on each subject. Two sessions, including one trial each were conducted per day. The complete experiment was not carried out on seven consecutive days, but was divided into three periods with 2 days of testing on two occasions and 3 days of testing in the last period. Each testing period started with 1 day when the reward reoccurred twice without the subjects having the opportunity to posses any appropriate tools.

Before the testing phase, a control for potential selection biases was conducted. This was done with the aforementioned three control subjects, two chimpanzees and one orangutan. Using different individuals in the control than in the experiment prevented unwanted learning. The chimpanzees had shared the same environment for the last 20 years, the orangutans for the last 3, and they were all naïve to the function of the tool as they had not received training on the apparatus. The control subjects were offered the opportunity to select from the identical board and objects as in the experiment. As in the experiment, the selection procedure was restricted to the selection room. Control subjects were offered the choice three times a day for a total of 14 times. There were no significant deviances from a chance distribution of choices (multinomial test). There were no significant choices of any of the specific objects (Fisher's exact test). The most selected object was the bamboo stick, however, not significantly. The chimpanzee male refused to select on two occasions and the chimpanzee female refused selection in one trial, this was conservatively calculated as hose selections. All together, the chimpanzees selected the functional tool three times each, and the orangutan selected it twice. From the absolute numbers of actual selections (excluding the refusals) a tendency, which might be interpreted that the familiar objects evoked a somewhat greater interest than the functional tool, can be derived. Importantly in this control the functional tool was not selected significantly more often than other items. We concluded that the specific objects did not evoke significant biases that would influence the main experiment.

Results

Out of the 14 trials performed, one chimpanzee (Linda), and the orangutan selected the functional tool in 100% of the trials. The other chimpanzee selected the functional tool in 13 of the trials. Their choices differed significantly from chance (Fisher's exact test, Linda and Naong $P = 0.0002$; Maria Magdalena $P = 0.0013$). One chimpanzee (Linda) brought and used the tool after the delay in 11 trials, while in the other three cases the tool was misplaced by her infant during the delay period (trial 3, 9 and 10). The other chimpanzee succeeded in bringing the tool in 12 trials. Her tool losses were also recorded as caused by Linda's playing infant (trial 5 and 10). The orangutan Naong brought the functional tool in 11 trials. In two of the unsuccessful trials he actually did bring the tool, though in a non-functional state as it was damaged from being carried in his mouth (trial 1 and 8). In the third case, the tool was dropped outside the enclosure (trial 11). All subjects obtained the reward when possessing the tool.

Discussion

Consistent with the findings of a previous study (Mulcahy and Call 2006), the results of this experiment show that great apes are able to select and save a tool for future use. Furthermore, the results show that great apes can select the correct tool in a location with no visual cuing to the future reward site. In the study of Mulcahy and Call (2006), it was demonstrated that apes were able to select a tool in the absence of the reward. This selection was conducted at the same site as the reward reoccurred. A selection at a different location with such a long delay has not been tested before (note however Mulcahy et al. 2005, for shorter delays) and is viewed as an important achievement in a planning context indicating a profound cognitive detachment from the perceptual stimuli (e.g., Tulving 2005). Furthermore, it should be noted that subjects were able to observe the absence of the apparatus, both before they were called inside the selection room and during their time of waiting with the tool. This means that they could not have selected a tool in reference to an existing reward at the reward site and that they could not have selected it to obtain an immediate reward after leaving the selection room. An associatively learned link between the tool and the reward is less likely due to the lack of short interval repetitions between the tool and the reward. However, the question of association is empirically addressed in Experiments 3 and 4. Another important aspect that extends this study beyond the previous one (Mulcahy and Call 2006), is that the subjects shared their waiting area with other individuals, instead of spending the delay time alone in a designated room. This presumably added a cognitive load to the subjects, not only when it comes to keeping the tool from getting lost, but also in the context of all the attention grabbing episodes that occur in ape enclosures in zoos. Among other things, this implies that subjects were not constantly cued by the presence of their tool. In other words it is unlikely that the desire for fruit soup was the predominant drive state during the delay. Being able to cope with such distracting factors is often relevant for future planning. The results of this experiment suggest behaviors based on advanced future oriented cognition.

Experiment 2: self-control in the face of a future reward

This experiment tested the ability to suppress the selection of an immediate reward in favor of a tool that would lead to a larger reward in the future. To show whether the subjects truly plan for a future need, they must override a motivation to satisfy a drive immediately in favor of a motivation to satisfy a different kind of drive in the future.

Methods

Subjects

The subjects, their surroundings and further conditions were identical to those described in Experiment 1.

Materials

All the materials were identical to the materials in Experiment 1, with one crucial exception. In the array of the above-described selectable objects, a favorite fruit of the subjects was included. In different enrichment activities, not related to this experiment, the zookeepers have established the favorite fruit to be grapes for all three subjects. Grapes had the status of a special treat for these subjects.

Procedure and design

The setup was identical to that of Experiment 1 (not including the training phase), except that the favorite fruit was established and added to the array of possible choices to evoke a strong immediate motivation that would compete with the future reward. In other words, subjects were called inside the selection room and offered a choice similar to that in Experiment 1, but with their favorite fruit included among the immediately selectable objects. As in the previous experiment, only one choice per trial was allowed and consistently, the time of delay was 70 min. In the context of this experiment, it should be noted that sometimes it is assumed that the steep discounting of the value of a future reward seen in animals results from the high risk of postponing a reward. To decline an immediate reward might lead to not obtaining any reward at all. By exposing subjects to the risk of tool loss due to group interactions, this factor was taken into account. Fourteen trials were conducted on each subject.

Data analysis

The expected choice of an animal not able to plan for the future is the immediate favorite fruit. Hence, the analysis of the data is based on this expectation. The question of interest in this experiment is which of the two represented reward types does the subject chooses: the immediate reward or the delayed reward. The distracter objects introduced in Experiment 1 were kept in Experiment 2, only to minimize the change in set up, avoiding any unwanted biasing that might have occurred by removing them.

Results

In 14 trials, one chimpanzee (Linda) selected the functional tool 8 times, the other chimpanzee selected it 11 times, and the orangutan 9 times. This is significantly above, expected choice of the immediate satisfaction (Fisher's exact test, Linda P = 0.0019 and Naong P = 0.0006, Maria Magdalena P = 0.00003). All subjects selected the fruit when they were not selecting the tool. Maria Magdalena and Naong both selected the tool in their first trial and Linda in her second. Maria Magdalena selected the grape in trials 2, 7 and 9. Naong selected the grape in trials 3, 5, 8, 10 and 13. Linda selected the grape in trials 1, 4, 5, 7, 8 and 13. The orangutan brought and used the tool in all the trials it was selected. Maria Magdalena did not succeed in bringing the tool in two trials (trial 1 and 8). One of the tool losses was caused by the playing infant. The other loss was a result of Maria Magdalena avoiding entering the room where she placed the tool, most likely because of the presence of the agitated dominant male. Linda did not bring the tool in four trials (trial 2, 3, 9 and 12). One of the losses was not observed. All of the other three got lost in everyday fighting.

Discussion

Subjects not able to plan for future needs are expected to choose the immediate favorite fruit reward, because they would be unable to represent the future fruit soup and the related need-state of satisfying the desire for it. It should also be noted that the tool lacks function until 70 min later, which arguably constitutes a considerable temporal distance for a non-planner. Moreover, selecting the tool does not eliminate any potential immediate craving for fruit soup and obviously it does not eliminate the craving for the grape. Therefore, selecting the tool without a reference to the future reward would appear maladaptive. The favorite fruit differed not only in quantity but also in quality from the future liquid reward. This removes the theoretical possibility that an act of self-control is governed by an immediate drive evoked by the grape (declining one grape in favor of more grapes). The level of performance in this experiment seems to be above or comparable to that of adult humans, both regarding to the time of the delays as well as to the percentage of exhibited self-control (Forzano and Logue 1992). This great ape ability in food related self-control tasks is also confirmed by

Rosati et al. (2007). The hypothesis of non-human impulsivity is seemingly not true for great apes in a planning context. These results strongly suggest that great apes are able to make choices favoring future needs in direct competition with immediate drive states.

Experiment 3: Controlling for associative learning

This experiment was designed to rule out that the subjects merely ascribe the tool an intrinsically high value detached from its future function. Such an association could explain the results in Experiments 1 and 2 without assuming future planning capacities. In other words, if the tool evoked an immediate craving in the same sense as the grape, then selecting the hose would reduce this drive state and consequently not be part of a planning behavior. This experiment controlled for such a possibility.

Methods

Subjects and materials

The subjects, their surroundings and further conditions were identical to those of the above-described experiments. The materials were the same as in Experiment 2, including the type of favorite fruit.

Procedure and design

As in Experiment 1, the subjects were given the choice between three non-functional tools and one functional tool. When the subjects had selected the functional tool, as expected, and thus had it in its possession, they were immediately offered a new choice including a second copy of the functional tool and a favorite fruit (in effect making the choice identical to the one in Experiment 2). Every other procedural aspect of this experiment was the same as in the previous experiments.

Fourteen trials were conducted on each subject.

Data analysis, results and discussion

If subjects merely attribute a strong positive value to the tool as such, then the result in the second pairing should mirror the outcome of Experiment 2. However, if instead the tool was valued as an instrument used for obtaining the future reward, then the favorite fruit would be the expected choice. The tool is a means to an end, and the future reward will not grow larger if more tools are selected. By selecting the grape in the second presentation, the subject maximizes the rewards. All three apes selected the fruit on each of the 14 trials. The results significantly deviate from chance (Fisher's exact test, $P = 0.006$), and do not mirror the results in Experiment 2. Note that this calculation is conservative, given that the results from Experiment 2 would make the tool the expected choice. This excluded associative learning as an explanation for the results in Experiments 1 and 2. This does not suggest, however, that the animals lacked positive associations in relation to the tool, just as humans probably do in relation to useful tools. Rather, it means that the association is not of the arbitrary nature that would be expected from mechanisms of associative learning.

It would not be suboptimal to occasionally choose the tool more than once, because the subjects did lose their tools in various group interactions in Experiments 1 and 2 at an average of 20% of the times per subject. In this experiment, the tool losses were at a similar level except for the orangutan (Linda 3 losses, Maria Magdalena 2 losses and Naong 0 losses). The heavy bias towards the grape in the second selection is most likely explained by the strong craving, the grape actually evoked in these subjects. It should be noted that the results of Experiments 2 and 3 are interrelated according to the status of the immediate reward. A less preferred immediate reward would probably yield better results on the self-control task and less clear results in the association control.

Experiment 4: pre-experiencing future particularities?

This experiment addressed whether the apes pre-experience their future tool actions. In the previous experimental choice situations, there is a chance that subjects might have known that the apparatus will reappear in the future, without pre-experiencing this future scenario. This experiment investigated such a possibility by introducing novel tools never encountered by the subjects before.

Methods

Subjects

The subjects, their surroundings and further conditions were identical to those described for Experiment 1, excep that the experimental subjects did not share the enclosure with each other during the delays to preclude unwanted learning about the novel tool.

Materials

The selectable objects used in this experiment differed from the ones in the previous experiments. For each of the 12 trials, a different set of selectable objects was displayed. In each trial, the functional tool as well as two of the three distracter objects was novel to the subjects. See Table 1 for a description of the novel tools and distracter objects. In all the trials, the choice also included a familiar bamboo stick previously associated with food acquisition (honey extraction).

Procedure and design

In each trial in this experiment, subjects selected among three novel objects, and a fourth object linked to food acquisition (though non-functional in this task). Out of the three novel objects, only one could function as a tool for obtaining the future reward. These tools appeared (to a human) as highly dissimilar from the soft, curled, and transparent hose used in previous experiments. The subjects were only given the opportunity of visual inspection of the objects. To avoid social learning, the subjects were not allowed to observe the others selecting, saving, or using the tool. An experimenter rotated each object for an equal amount of time and at slow speed in front of the ape. The functional tool was rotated as the second or the third object in order to minimize possible biasing effects due to the first or last position. To preclude potential gaze cuing, the experimenter focused his or her gaze behind and slightly above the subject, without having eye contact or gazing directly at the objects. A tool was used only once in a single trial because its novelty was lost after one use.

Control

A control was conducted to find potential biases for selecting the novel functional tool without the relevant connection to the reward apparatus. This control was made with the three apparatus naïve subjects that took part in the control in Experiment 1. The control selections were conducted in the selection room with materials identical to those of the main experiment. Consequently, 12 trials were conducted per control subject. As in the control of Experiment 1, a subject carried out three control trials a day. The novel functional tool was not selected significantly above chance (Fisher's exact test). The male chimpanzee selected the functional tool in two trials (trials 4 and 5). He refused selection in the last four trials (probably indicating lack of interest in the objects). The female chimpanzee selected the functional tool in three trials (trials 2, 8 and 12). This was also true for the female orangutan that selected the tool in trials 2, 8, and 10. All three control subjects chose the same distracter object in three trials (the blue plastic car used in trial 1, the multicolored necklace used in trial 3 and the discarded wrist watch used in trial 6). In trial 8, two of the control subjects selected the functional tool. Based on these findings, we concluded that potential biases were at an acceptable level for using the objects in the main experiment.

Results

The orangutan selected the functional tool in 11 of the 12 trials (failed in trial 9). One chimpanzee (Linda) selected the functional tool in ten trials (failed in trial 7 and 9) and the other chimpanzee in nine trials (failed in trial 6,7 and 9). The novel functional tool was selected significantly above chance by all three subjects (Fisher's exact test, Naong $P = 0.003$, Linda $P = 0.012$, Maria Magdalena $P = 0.039$).

In the successful choices, the subjects brought the tool to the reward room after the delay and used it appropriately with no observable hesitation (see Fig. 1). Furthermore, they did not try to use the non-functional tools in the trials where such were selected.

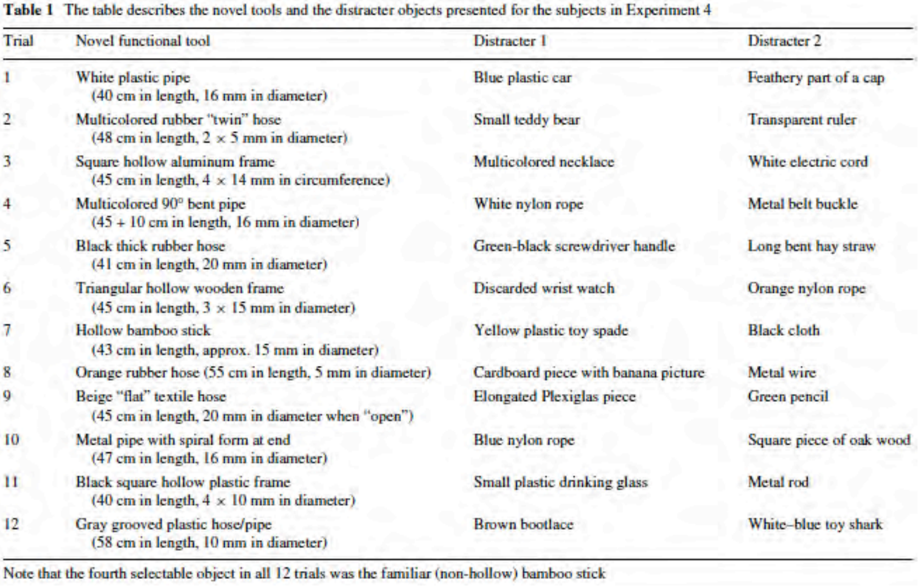

Table 1 The table describes the novel tools and the distracter objects presented for the subjects in Experiment 4

Trial	Novel functional tool	Distracter 1	Distracter 2
1	White plastic pipe (40 cm in length, 16 mm in diameter)	Blue plastic car	Feathery part of a cap
2	Multicolored rubber "twin" hose (48 cm in length, 2 × 5 mm in diameter)	Small teddy bear	Transparent ruler
3	Square hollow aluminum frame (45 cm in length, 4 × 14 mm in circumference)	Multicolored necklace	White electric cord
4	Multicolored 90° bent pipe (45 + 10 cm in length, 16 mm in diameter)	White nylon rope	Metal belt buckle
5	Black thick rubber hose (41 cm in length, 20 mm in diameter)	Green-black screwdriver handle	Long bent hay straw
6	Triangular hollow wooden frame (45 cm in length, 3 × 15 mm in diameter)	Discarded wrist watch	Orange nylon rope
7	Hollow bamboo stick (43 cm in length, approx. 15 mm in diameter)	Yellow plastic toy spade	Black cloth
8	Orange rubber hose (55 cm in length, 5 mm in diameter)	Cardboard piece with banana picture	Metal wire
9	Beige "flat" textile hose (45 cm in length, 20 mm in diameter when "open")	Elongated Plexiglas piece	Green pencil
10	Metal pipe with spiral form at end (47 cm in length, 16 mm in diameter)	Blue nylon rope	Square piece of oak wood
11	Black square hollow plastic frame (40 cm in length, 4 × 10 mm in diameter)	Small plastic drinking glass	Metal rod
12	Gray grooved plastic hose/pipe (58 cm in length, 10 mm in diameter)	Brown bootlace	White–blue toy shark

Note that the fourth selectable object in all 12 trials was the familiar (non-hollow) bamboo stick

Discussion

The results of this experiment indicate that the apes pre-experience the future tool function and its use. This strengthens the likeliness that episodic prospection is involved in the tool selection tasks in this study. Stimulus generalization does not offer a sufficient explanation because the subjects were sensitive to the functional aspects of the tools rather than to arbitrary features. The alternative functional tools in this experiment markedly differed from the original tool used in the previous three experiments, and several of the distracters shared features with the original tool. The two features common in the functional tools were a length above the minimum required for reward retrieval (approximately 38 cm), and holes in both the ends. However, these features notably varied from the original tool. Both the longest and the shortest of the novel tools were shorter than the original (12, respectively; 30 cm shorter). The holes in the novel objects did not differ only in diameter (up to 16 mm larger) but also in shape (round, square and triangular) and numbers (two holes at each end in the tool in trial 2). Furthermore, several of the distracter objects carried features that were present in the original tool (see Table 1), for example, transparency (trial 2, 9, 11) or thin elongation (trial 3, 4, 5, 6, 8, 10, 12). Given the varied nature of the shared features in the functional tools, and that the original tool shared features with several distracters, it is fair to assume that the results show a tool selection based on the

Fig. 1 Chimpanzees are obtaining the liquid reward with different tools. Linda (**a**) is using the hose that constituted the functional tool in the first three experiments. Maria Magdalena (**b**) is using the hard pipe that was displayed in trial 1 in experiment 4. Note that the hose is utilized from below with the subject sitting on the floor while drinking, whereas the pipe requires a different drinking position.

functional properties. This is in line with Call (2006), who noted that apes are better in understanding the causal properties of the physical world than in associating arbitrary stimuli and responses.

A more complicated question is whether these results reflect semantic or episodic prospection. It could be argued that even if subjects selected the tool because of its function, they might have followed a semantic rule instead of pre-experiencing the reward retrieval situation. However, it cannot be argued that the actions towards the upcoming event are governed by semantic prospection solely because the future target event is repeated through the trials. The selection situation includes particularities that must be compared with the upcoming event, requiring unique comparisons in each trial. Nevertheless, it cannot be entirely excluded that semantic rules offer the main mechanism in this kind of single trial generalizations of non-discrete features to future functions; however, the concept of semantic prospection still seems to be too vague to offer guidance. Given our current understanding, the results in this experiment indicate pre-experiencing of the particularities of a future event. The lack of observable hesitation in the tool use was striking and would suggest a high fidelity in the envisioning of the function and the necessary manipulations.

General discussion

In several important aspects, this study extends beyond previous knowledge about prospective cognition in great apes (Mulcahy and Call 2006). It shows that great apes are capable of acting towards a future state although experiencing a strong current and competing drive. Self-control in relation to such highly delayed events as described here is till date not reported for non-human animals. Furthermore, it is shown that great apes can generalize a function from a completely novel object to a future use. This ability seems paralleled only by human envisioning of a future event. Some of the crucial data in the study make it unlikely that the behaviors surrounding the tools should be a result from associative learning or semantic rule following, rather than from actual planning. It is also shown that great apes are capable of selecting objects needed for a much-delayed future in a different and not currently perceived location. Furthermore, it is demonstrated that great apes are able to cope with planning tasks under the presumably high cognitive load, produced by taking part in everyday social life. When amalgating the experiments of this study, it is strongly suggested that great apes can plan for the future (see Table 2 for overview of the experimental results).

There is a widespread tendency to use associative learning in explanations of non-predisposed animal behavior. Such explanations do not account for the key behaviors exhibited by the subjects in this study. Only once during the study did subjects obtain the tool with an immediate accessible reward present, and this was on the first occasion they used the hose. Thereafter the delay between acquiring the tool and the occurrence of the attainable reward lasted for at least 1 h. Furthermore, the subjects did not always obtain the reward even if the correct tool was selected, because the tool sometimes got lost in various group interactions during the delay (a mean of approximately 20% of the times per subject). Such circumstances are not readily compatible with associative learning. Examples of associative learning from single occasions are few and seemingly connected to species-specific predispositions such as innate defense behaviors (Bolles 1970) or preparedness (Seligman 1970) (like the development of fear of snakes or specific food avoidance when being nauseated). It appears invalid to assume these, or similar, mechanisms to be at work in this series of experiments. The exercise of self-control is an act of overriding hardwired impulses, and it would require extensive training, if at all possible, to associatively learn the level of self-control exhibited by the subjects. Obviously such training was not given. And, if selecting the tool instead of the favorite food was actually a result of training, the subjects would not have selected the tool in their first or second trial and there would have been a visible learning curve in the data. If there was an associatively learned connection between the plastic hose and the future reward, the tool would carry an intrinsic value detached from cognitive considerations about possible future events. To explain the outcome of Experiment 2 in such associative learning terms, this value would have had to be even greater than that of the favorite fruit. Experiment 3 clearly and decisively demonstrates that this is not the case, and thereby also shows that associative learning has not been at work in Experiment 1. Experiment 4 does not constitute fertile ground for associative learning mechanisms, because the tools and their functions were never learned but were completely novel and highly dissimilar from the original, as well as from each other.

Another possible explanation would be that the results reflect semantic prospection. However, the current knowledge about semantic prospection is scarce. The area appears to be uncharted and does not rest on a direct empirical ground. When further developed, the concept might very well prove its explanatory value. Nevertheless, given the present understanding and definition it seems likely that the result in at least Experiment 4 would be incompatible with semantic prospection. When turning to the potential status of the needs in this study, it is worth pointing out that it is improbable that immediate needs governed the subjects' choices in the successful trials. This would have required that all the subjects in 54 trials experienced a desire for fruit soup already when entering the selection procedure. Desire for fruit soup is rather specific and seemingly far from the expressions of more common basic biological needs (any general thirst could have been slaked at any time by the drinking facilities in the enclosures). Considering all feasible

Table 2 The table shows an overview of the number of appropriate responses (from the view of a planner)

Subject	Experiment 1 Selecting the functional tool (max $n = 14$)	Experiment 2 Selecting the functional tool (max $n = 14$)	Experiment 3 Selecting the favorite fruit (max $n = 14$)	Experiment 4 Selecting the novel functional tool (max $n = 12$)	Total experiments (max $n = 54$)
Naong (*Pongo abelii*)	14	9	14	11	48
Linda (*Pan troglodytes*)	14	8	14	10	46
Maria Magdalena (*Pan troglodytes*)	13	11	14	9	47

It would be difficult to collapse the statistics from all four experiments, though it is noteworthy that all subjects perform the appropriate key behavior in more than 85% of the total of the trials drive states that could have been experienced by the subjects at any given moment, it would arguably yield an extremely low chance that the immediate need in the moment prior to the selection was that of fruit soup. The chances that a potential desire is evoked during the selection moment seem much greater. And, such a trigger is not always equivalent with a trigger that evokes an immediate need, even less so if the stimuli are not associatively learned. Although previously discussed, a brief recapitulation might be appropriate to further appreciate this point. Experiments 2 and 3 were designed to create a strong immediate desire for the instantly available favorite fruit. It is hypothesized that an animal mentally stuck in the present is unable to circumvent the immediate reward in favor of something occurring in the future. The theoretical consequence is that any potential immediate needs related to fruit soup are instead shifted towards the instant reward. Unless, the stimulus related to the future reward evokes a drive that can be satisfied by attaining the stimulus itself, and thereby in consequence making the experimental situation a choice between two immediate rewards. Experiment 3 excludes such a possibility from this study. Another viable alternative to select the future oriented stimulus is that a prospection evokes a potential craving towards the future reward, that is anticipating the mental state of a future need.

The results of this study entail that capacities central to humans evolved much earlier than previously believed (e.g., Noble and Davidson 1996; Macphail 1998; Osvath and Gärdenfors 2005; Suddendorf and Corballis 1997). Furthermore, they imply that apes use cognition described as self-conscious when exhibited by humans. The results fit well with the neurological data indicating an experienced inner mental world in chimpanzees (Rilling et al. 2007). The findings are interesting when considering the study of extant great apes as well as when discussing the evolution of human cognition. For example, the advanced social strategies displayed by chimpanzees (e.g., de Waal 1982), or the chimpanzee customs surrounding warfare, hunting or tool use in the wild (e.g., Boesch and Boesch-Acherman 2000), might be given richer interpretations than accepted before. When it comes to human cognitive evolution the data support the theories claiming that the skill for future need planning phylogenetically precedes language and even facilitates the evolution of the communicative system of humans (Osvath and Gärdenfors 2005; Suddendorf and Corballis 1997).

It cannot be claimed that the planning skills of humans are identical to those of the other great apes, but rather that there does not seem to exist a profound evolutionary discontinuity in the ability to foresee future needs. To gain further understanding of the phylogeny of planning skills, and to get deeper insights into the abilities that are at play in this specific study, it would be fruitful to conduct a close analog of this series of experiment on gibbons (the closest relatives to the great apes), on small children (in the development of prospection), and on representatives of the rare clinical group, lacking episodic abilities (still having intact semantic systems). Additionally, in the interest of the broader endeavor to understand the prospective skill as a biological and cognitive phenomenon, it would be productive to compare the performance of distantly related species on tasks similar to this study.

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Paper II

Repetition is the mother of learning.

Unknown (latin proverb)

How farsighted is the Bischof-Köhler hypothesis?

Mathias Osvath

Abstract Suddendorf, Corballis and Collier-Baker (Anim Cog 12: 751-754, 2009) comment upon a study on great ape forethought (Osvath and Osvath, Anim Cog 11: 661-674, 2008). The study consisted of four experiments aimed at investigating forethought in chimpanzees and orangutans, with focus on examining whether the episodic cognitive system is likely to explain the exhibited planning. This cognitive system has been regarded as exclusive to humans. The Bischof-Köhler hypothesis explicitly states that planning for a future need is outside the realm of non-humans. We argued that the study in question suggests episodic abilities and challenges the Bischof-Köhler hypothesis. Suddendorf *et al* are not ready to accept this claim. They give a detailed critique on each experiment in an attempt to uphold the view on human uniqueness in this domain. Here I point out the misapprehensions and weaknesses revealed in their critique, and maintain my previous interpretation backed with additional recently published findings.

Keywords: foresight, planning, mental time travel, the Bischof-Köhler hypothesis, episodic memory, great apes

The recent evidence for the ability to plan for the future in great apes and corvids (Mulcahy and Call, 2006; Osvath and Osvath, 2008; Dufour and Sterck, 2008; Osvath, 2009; Raby et al, 2007; Correia et al 2007) is intriguing, although not surprising. Reliably forecasting the future would certainly be adaptive in an array of niches. Accordingly, a large number of prospective behaviors have been selected for during the history of life. Many nervous systems comprise different forms of high and low level mechanisms simulating potential futures on different timescales: from split second motor anticipation to imagining days to come (e.g. Hesslow, 2002).

In recent years the concept of mental time travel has attracted attention from researchers of animal cognition. Mental time travel is a key feature of human cognition, and denotes the ability to mentally project the self into past and future events. A special characteristic of this ability is a re- and pre-experience of the event detached from the current situation. Such an experience is related to a type of self-awareness, often referred to as autonoetic (e.g. Tulving, 2005). The cognitive system that facilitates such self-aware re- or pre-experience is thought to be the episodic system, which initially was theorized to be a memory system but later showed also to construct potential future events.

Suddendorf and Corballis (1997) spurred empirical research into future planning in animals by proposing the Bischof-Köhler hypothesis. Its implication is that only humans are able to travel mentally into the future. Originally the hypothesis was formulated in terms of negatives "[…] animals other than humans cannot anticipate future needs or drive states and are therefore bound to a present that is defined by their current motivational state." More recently this has been re-expressed as "[….] only humans can flexibly anticipate their own future mental states of need and act now to secure them" (Suddendorf and Corballis, 2008).

There is no obvious adaptive reason for that planning for a future motivational state would be beneficial for humans alone. There is an abundance of behaviors in nature which lead to the satisfaction of future drive states. However, there is a lack of unambiguous observations of cognitively driven future planning for such motivational states in the spontaneous actions of non-human animals. This dearth is probably a reflection of the inherent methodological limitations in identifying and isolating the mental state of an animal in the absence of language. I have recently, however, reported specific observations of spontaneous future need planning in a chimpanzee, which contradicts the Bischof-Köhler hypothesis (Osvath, 2009). The hypothesis was also challenged in an experimental study on two species of great apes (Osvath and Osvath, 2008). For suggestions on behavioral criteria for planning for future needs, see for example Tulving (2005), Suddendorf and Busby (2005); and for the criteria adhered to in the study in question, see Osvath and Osvath (2008).

In Osvath and Osvath (2008) over the course of 54 trials two chimpanzees and one orangutan responded appropriately from a planning point of view on 85-89% of occasions. Suddendorf, Corballis and Collier-Baker (2009) have responded to these findings with a number of criticisms of our study, which aim to uphold the Bischof-Köhler hypothesis and the idea that the episodic cognitive system is unique to humans. They seem to rebut our suggestion that the findings are best explained by cognitive functions in the planning domain which are shared by apes and humans (i.e. episodic abilities), and instead propose that these complex behaviors are better accounted for by associative learning and some less clear cognitive mechanisms. Here I discuss their comments and suggest that they have ignored the stated aim of each individual experiment and the cumulative evidence from the combined experiments which is the basis of our suggestion that these studies demonstrate episodic forethought. Table 1 gives an overview of the commentators' critique of each experiment and our response.

In Experiment 1 the apes were taught, on a single occasion, to use a specific hose as a straw to obtain a fairly large amount of a favored fruit soup. The subjects were subsequently close to 100 % in selecting the hose from a choice of items offered to them. This choice was made in a room unconnected with the fruit soup and 70 minutes before the fruit soup was made available. Three other apes naïve to the use of the hose as a functional tool were given the same choice of objects in the same location. These apes did not select the functional tool significantly more often than any other item. As stated in the original paper the naïve apes were used specifically to control for any possible biases in the materials or the selection procedures used. No such biases were found.

Table 1 This table summarizes the aims of the experiments of the study, the results, the comments given by Suddendorf et al and my responses to these comments.

	Experiment 1 ***Baseline***	**Experiment 2** ***Self-control***	**Experiment 3** ***Associative learning***	**Experiment 4** ***Envisioning***
Aim	Test whether a tool with a future function is selected.	Test the ability to overcome an immediate desire in favor of a future one.	Control for whether the tool selection is associatively learned.	Test if novel items can be distinguished based on future functional features.
Result	The result is positive. All subjects select the tool significantly more than expected.	The result is positive. All subjects selects the delayed reward significantly more than expected.	The result is positive. All subjects selects the immediate reward significantly more than expected	The result is positive. All subjects selects the functional tool significantly more than expected.
Comments by Suddendorf et al	I. Associative learning is not excluded. II. Immediate desires not excluded.	I. Associative learning not excluded.	I. Immediate desires not excluded.	I. The cognitive mechanisms underlying the results are unclear. II. Apes have representational skills offering them some foresight.
Response to the comments	I. Not the aim of this experiment, but of Experiment 3 (see Result). II. Not the aim of this experiment, but of Experiment 2 (see Result).	I. Not the aim of this experiment, but of Experiment 3 (see Result).	I. Not the aim of this experiment, but of Experiment 2 (see Result).	I. Based on current understanding, and the phylogenetic proximity, episodic representation would be a parsimonious explanation. II. Yes.

We suggested that the results of Experiment 1 were compatible with future-oriented cognition but did not exclude the possibility of associative learning although we thought this explanation unlikely. We did not conclude that the results of this experiment alone demonstrated planning for a future event.

Suddendorf and colleagues propose that the experience of sucking half a liter of fruit soup through the straw resulted in one trial associative learning, leading to the apes', who had that experience, choosing the straw on each of the following 14 trials, while the apes who had not had that experience did not. This explanation seems to confuse 'association' with 'associative learning'. Contrary to their comment that we assert that it would be "invalid" to assume one-trial learning (p.751), one-trial learning was pivotal to the experiment and an integral part of the design. However single trial learning is not the same as associative learning. If one-trial associative learning had taken place resulting in the apes selecting the hose in anticipation of the immediate delivery of fruit soup then learning theory would predict that the failure of the reward to materialize in the very near future would extinguish that behavior over the next few trials. It would seem to be at odds with associative learning theories to propose a complex sequence of relearning the associative link on every occasion that the hose is used to obtain fruit soup even though there is no temporal contiguity between the selection of the hose and the availability of fruit soup.

We do comment in our general discussion that examples of associative learning from single occasions are few and often seemingly connected to species-specific predispositions such as innate defense behaviors (Bolles, 1970) or preparedness (Seligman, 1970).

Suddendorf and colleagues seem also to be under the misapprehension that the control in the first experiment was designed to test whether the tool selection resulted from a planning action or from associative learning. They observe: "the finding of Experiment 1 that the control group did not select the straw above chance while the experimental group did, may simply reflect [their] differential experience" (p. 751). As discussed above the precise purpose of the control was to establish that the choice of the experimental apes was as a consequence of their "differential experience" and not due to some bias in the materials or the procedures. Incidentally, giving both groups the same experience of associating the straw with drinking fruit soup would not have been an effective control as the commentators suggest. If members of the control group had subsequently selected the hose it could just as well have resulted from forethought as from associative learning.

Having dismissed the apes' selection of the functional tool as associative learning arising from an immediate expectation of fruit soup the authors go on to argue that the apes then discard the tool as the reward is not forthcoming and forget about it. They are then prompted to remember where they have left it when cued by the arrival of the fruit soup. Their argument, then, seems to be that there is repeated one-trial learning of an association between the hose and fruit soup which is extinguished when the fruit soup does not materialize followed by a memory that the tool can be used to obtain fruit soup and its location once the fruit soup becomes available but that the apes do not in any way connect this to their previous selection of the tool. Apart from the fact that this is a rather more convoluted explanation of the behavior of the apes than that they remember that the hose can be used to obtain fruit soup and select it in anticipation of using it in the future, this explanation is not consistent with their critique of other experiments in this study. It should also be noted that Experiment 3 was designed to control for associative learning, and not Experiment 1 (see Table 1).

In our second experiment the apes were offered the same selection of items as in Experiment 1 as well as a piece of a favorite fruit, a grape. The ability to disregard an immediately available reward in favor of a delayed larger one is an expression of self-control and cognitive executive mechanisms. Self-control is needed for the ability to plan outside the scope of the current desire. Until recently, the prevailing view has been that non-human animals are impulsive and only able to defer a reward some seconds or at maximum a few minutes. In our second experiment the apes showed that they were able to forgo an immediate reward (a grape) in favor of a tool that might lead to a future reward (the fruit soup). One of the chimpanzees selected the hose in 79 % of the trials while the other selected it 57 % of the time and the orangutan chose it 64 % of the time.

Suddendorf and colleagues argue that while the functional tool was selected significantly more often than zero it was not selected significantly more often than the grape. However, setting the expected choice at chance level is not appropriate when assessing whether a subject is exercising self-control or not. An animal not exercising self-control would be expected to choose the immediate reward. The percentage of occasions on which the subject by-passes the immediate reward in favor of a delayed larger one, reflects the *degree* of self-control rather than chance behavior. In food-related self-control experiments many humans would probably have difficulties in reaching the rigorous standards proposed by the commentators. In passing could be noted that approximately 15 % tool selections could be expected by chance, and still allowing the lowest performing ape to produce significant results – the figure is almost doubled for the best performer.

The authors further argue that associative learning accounts for the selection of the hose by the apes: "By this point, the association between tool and reward must certainly have been strong, and one might have expected the apes to persevere" (p.752). However, as they themselves point out in their critique of Experiment 1, the selection of the tool was not rewarding in associative learning terms as the fruit soup never followed the selection of the tool. In any event, Experiment 3 was designed to control for the possibility of associative learning. Suddendorf and colleagues surprisingly say that Experiment 2 lacks a control. As stated in our paper: Experiment 3 is the control for Experiment 2. It is not obvious in what way the control that they suggest – a situation in which the apes have no reason to expect a future reward – would be more convincing than Experiment 3.

Despite the unlikelihood of associative learning accounting for the results of the first two experiments we conducted a third experiment to specifically control for this possibility. One of the key features of associatively learned stimuli is that they are arbitrary; the stimulus that predicts the reward has an intrinsic value independent of its functional value as long as it is a reliable predictor of the reward.

In Experiment 3 we gave the apes the opportunity to select two objects from two different trays, one object from each tray. They were first offered a tray with the same choice of objects as in Experiment 1, which included three distracter items and the hose. All the apes selected the hose. They were then immediately offered a second tray, which held the same items as Experiment 2, i.e. the distracter items, the hose and the grape. If the hose had an associatively learnt intrinsic value the apes would be expected to choose it from the second tray as well as the first. At least to the extent that results in the second selection would mirror the results of Experiment 2. In fact, the apes invariably chose the grape from the second tray.

The commentators suggest that the apes selected the functional tool first "in expectation of *immediately* receiving the associated fruit soup" (this despite the fact that the fruit soup had never immediately followed the selection of the hose) "and then, having secured the necessary and sufficient tool for obtaining it, they selected the grape on their second choice" (p. 752). The authors here seem to be acknowledging that the results are explicable by the apes having an understanding of the functional use of the tool and an anticipation of using it in that context rather than it having an arbitrary intrinsic value. Precisely what this experiment was designed to control for. The experiment did however not address the question of *when* (immediately or in the future) a reward was expected; the competition between current and future drives was addressed in Experiment 2.

The fourth and last experiment in this study was designed to test whether the apes mentally relate to particularities of the future. Such an ability would be an indication of episodic abilities as it suggests that the animal is pre-experiencing specific unique features of a future event. We presented the subjects with three novel and one familiar items. One of the three novel items could be used to drink fruit soup from the familiar apparatus. The familiar item was a bamboo stick, which had previously been used by the apes to extract honey from a log. The apes were given the opportunity to visually inspect the items. They were then allowed to select one of them. In the 12 trials the experimental apes selected the functional novel tool significantly more often than the other items while the control subjects did not. The results seem particularly impressive, as the novel tools were highly dissimilar in appearance. Furthermore the apes used the unfamiliar tool to obtain the fruit soup without observable hesitation even though several of the tools required using a different body posture than the original hose.

Suddendorf and colleagues concede that the apes seem to have learnt relevant affordances rather than simple stimulus-response relations, which they do not find surprising as they acknowledge that apes are poor at arbitrary associations. In their view the apes are using advanced representational skills in this experiment. They go so far as to suggest that our study comes close to establishing that apes have some capacity for foresight. However, they fail to give an alternative explanation to episodic abilities. How the suggested affordances are implemented into the future directed behavior remains unaccounted for. It seems that they think the apes are using advanced cognitive skills in this final experiment but not in the others in which they suggest that, despite the evidence that we present to the contrary, the apes are relying on their rather poor associative learning abilities to perform highly demanding tasks.

Furthermore, the commentators criticize the interpretation of the findings, by claiming that the apes were inappropriately cued in the planning situation. Suddendorf and colleagues do not take into consideration the discussion in our original paper on what kind of cuing that seem probable in these experiment: a cuing compatible with pre-experiencing a future event. Non-cued planning appear to be close to a contradiction in terms, as such plans would arise in the mind more or less by chance and not be related to a purposeful intention, which is a *sine qua non* of planned behaviour (see original paper for a more comprehensive discussion). The commentators do not themselves offer a suggestion of what type of cuing that would be compatible with planning.

Single studies rarely settle questions concerning complex cognitive traits, neither does the study in question. However, it notably challenges the Bischof-Köhler hypothesis, as do the recent report on a spontaneously planning chimpanzee (Osvath, 2009). Both of these findings are much suggestive of the existence of episodic mechanisms in great ape cognition. As the current field stands, episodic abilities offer a parsimonious explanation of the findings. It requires convoluted alternative accounts, if not assuming phylogenetic continuity in episodic abilities between our closest living relatives and us. There is no evidence that humans alone possess neurological structures for conscious sensory-motor simulations detached from current input - on the contrary (e.g Hesslow, 2002). Indeed, there is evidence suggesting that chimpanzees have brain activities that correspond to those of humans at so called wakeful rest; a state associated with conscious simulation of behavior, planning and pondering the past (Rilling et al, 2007). Recently, results suggesting episodic memories in great apes have been presented (Martin-Ordas et al, 2009). Such memories constitute the other end of the mental time travel continuum.

Amassing data throw doubt on the notion that the episodic cognitive system is exclusive to humans. One might ask whether the human ability, as well as non-human abilities, is optimally understood and explored by maintaining seriously challenged hypotheses. It does not appear farsighted to uphold the Bischof-Köhler hypothesis in the light of growing evidence. The hypothesis hoisted empirical studies and knowledge to new levels, but it is time to look ahead towards other hypotheses.

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Paper III

Humans, by contrast, plan the future regardless of present need; a full-bellied lion is no threat to nearby zebras, but a full-bellied human may be.

T. Suddendorf and M. Corballis, (*Mental time travel and the evolution of human mind, 1997*)

The other side of the coin – when currently satiated by the reoccurring reward

Mathias Osvath

Competition with drive states can be performed in many ways. Self-control is perhaps one of the most potent examples of this ability. In particularly because it is fairly easy to control this process experimentally. However, it seems to be of equal ecological importance to be able to cope with the other side of the coin – to act towards the future when currently experiencing what could be thought of as a negative need. In other words, to suppress or disregard the current satisfaction to an extent that makes it possible yet again to be satisfied when the drive state reoccurs. Examples of cognitively overcoming physiological homeostasis in order to repeat the state of equilibrium could be filling up a water bottle when quenched, cooking or shopping for food when thoroughly satiated or preparing a night's rest in the morning.

In a pilot study we tested this ability on the male orangutan that participated in the previously described experiments. This experiment was based on tool behavior in relation to a large food reward. The question to be answered was whether or not the orangutan would save the tool leading to the large reward immediately after the consumption of it. The first step in this experiment was to get an approximation and hence a control of when satiation was reached by the subject when offered this kind of reward. The food reward in this experiment was of the same kind as in the previous one: A thick and sweet fruit soup (rose hip berry soup). To a human, this soup is highly satiating due to its syrupy and sweet character. It has a high energy content with about 60 kcal per deciliter. To control for satiation, the orangutan was offered to drink from a bottle filled with 1.5 liters of soup. The subject was given this bottle of drink on three different occasions months apart. Two keepers with more than 30 years of experience of working with great apes, independently of each other made a judgement, based on the behaviour of the ape, when it started to become satiated. They agreed that drinking pace and general eagerness seemed to fade after about 1 litre was consumed. Based on these observations the reward size was set to 1 litre in the experiment. In the experiment a paper box containing the reward was placed outside one of the two interconnected enclosure, in a counterbalanced fashion, three times a day with pseudo-randomized time intervals between.

A thick and rather stiff rubber hose was the only tool that could be used to obtain the reward. If other tools were used, like sticks, then either the paper apparatus would break or the acquired amount of the reward would be extremely limited.

No training on the tool or on the apparatus were given before the experiment. The orangutan was not informed about the reoccurring nature of the reward prior to the experiment. The experiment started with the tool being planted within one of the two interconnected enclosures from where the subject was currently barred. The subject could not see the tool being planted. Then the ape was let into the enclosure and it was recorded when the tool was found. In this first trial it took 5 minutes before the tool was discovered. When 1 hour and 30 minutes had past, the subject was let into the other enclosure outside where the baited apparatus was installed. The orangutan had by now shredded the tool into tiny pieces and therefore could not obtain the reward. He tried using sticks and cloths, though with meagre results. This reward reoccurred three times during the day in and outside the different enclosures with time intervals no less than one hour and no more than three.

The next day the tool planting procedure was repeated. This time it took three minutes before the orangutan found it. After this followed an impressive sequence of three whole days when the orangutan kept track of and brought the tool with him when moving between the enclosures and going to rest at night. During these three days the orangutan successfully obtained the reward three times per day. And the key behaviour, saving the tool by bringing it with him after finishing up the reward, was recorded 10 times. The experiment had to be aborted after three days because of health considerations relating to the extremely high energy and sugar content in the reward.

A control was also conducted by planting a non-functional tool following the same set-up as in the previous experiment. A blue plastic string with the same length as the hose was planted. The subject found it after 1 minute. It was not destroyed, but it was not saved either or brought to the next enclosure. The reward reoccurred three times daily, but the orangutan ignored the string as a tool (and instead returned to using sticks) and did not exhibit any saving behavior related to it. Again, this confirms that tools are saved in accordance to their future function. This pilot study indicates that apes are able to act towards a reoccurring opportunity to satiate a drive that is currently satiated. Firmer results on this ability would be achieved if the trials were extended with the same subject, as well as including other individuals. Furthermore, it should be noted that it probably does not require much effort for the ape to save the tool – this fact could be modified to reach further understanding in the planning skills of great apes. Nevertheless, these findings give additional verification to the hypothesis that great apes are able to plan for future states.

Figure 1. The male orangutan Naong negotiates the problem of getting the trapped honey from the holes drilled into the log (enrichment activity unrelated to the described study).

Papers IVa & IVb

Ape of things to come. The ape who changed our view of humans.

The Guardian *(*front page, 10th of March 2009)

Spontaneous planning for future stone throwing by a male chimpanzee

Mathias Osvath

Planning for a future, rather than a current, mental state is a cognitive process generally viewed as uniquely human. Here, however, I shall report on a decade of observations of spontaneous planning by a male chimpanzee in a zoo. The planning actions, which took place in a calm state, included stone caching and the manufacture of discs from concrete, objects later used as missiles against zoo visitors during agitated chimpanzee dominance displays. Such planning implies advanced consciousness and cognition traditionally not associated with non-human animals [1]. Spontaneous and unambiguous planning behaviours for future states by non-humans have not previously been reported, and anecdotal reports, describing single occasions, are exceptionally scarce [2–4]. This dearth of observations is arguably the main reason for not ascribing cognitive foresight to non-human animals [1]. To date, the surprisingly few controlled demonstrations of planning for future states by animals are experimentally induced behaviours in great apes [5–7] and corvids [8,9]. The observational findings in this report suggest that these laboratory results are not experimental artefacts, at least in the case of great apes.

Stone throwing toward a crowd of people has an instant and dramatic effect, and was a way to evoke reactions across the water moat that enclosed the chimpanzee. During the first three years during which this male chimpanzee held the dominant position, stone hurling was infrequent. This was probably because the outdoor island compound rarely contained stones immediately attainable in a display. In early June 1997, however, stone throwing increased dramatically, including several throws per display. This prompted zoo personnel to take precautionary measures. One morning the chimpanzee island was swept, revealing five stone caches containing three to eight stones each, as well as individual stones between the caches, located along the shore facing the public area. Algae coating indicated that the stones originated from the adjacent waterbed (Figure 1). On subsequent days a caretaker placed herself in a blind to systematically observe the chimpanzee's behaviour. On five consecutive days, before the zoo opened, the chimpanzee gathered stones from the water and placed them in caches. Later on each of these days, the stones were used as ammunition during displays (see Supplemental data available on-line for details).

In June 1998, the chimpanzee began to add pieces of concrete to the ammunition (Figure 1). Instead of restricting the stone gathering to the waterbed, he exploited the concrete rocks located at the centre of the island. In a sub-arctic zoo, concrete structures can be vulnerable to water entering and freezing in micro-cracks, partially detaching the surface layer. This is mostly invisible, but may be detected from a hollow sound when knocking on damaged areas. The chimpanzee was observed to gently knock on the concrete rocks, from time to time delivering harder blows to break off the detached surface section in discoidal pieces, and sometimes breaking these into further smaller fragments. These manufactured missiles were often transported to the

Figure 1. Projectiles used in display. A concrete disc and two stones thrown at visitors in July 2008. The scale is in centimetres.

caches at the shoreline. Since the initial findings, caretakers have removed hundreds of caches. The gathering of stones has been observed on at least 50 distinct occasions, and the manufacturing of the concrete dishes has been directly observed at least 18 times. However, concrete pieces were regularly present in the caches or individually along the shore.

In order for a behaviour to signal planning for a future state, the predominant mental state during the planning must deviate from the one experienced in the situation that is planned for. The above-described behaviour is clearly identifiable as planning for a future state. The chimpanzee has without exception been calm during gathering or manufacturing of the ammunition, in contrast to the typically aroused state during displays (Figure 2). The gathering and manufacturing has only been observed during the hours before the zoo opened, excluding potential triggering from the presence of zoo visitors. The delay between the gathering and the throwing of the stones is typically several hours.

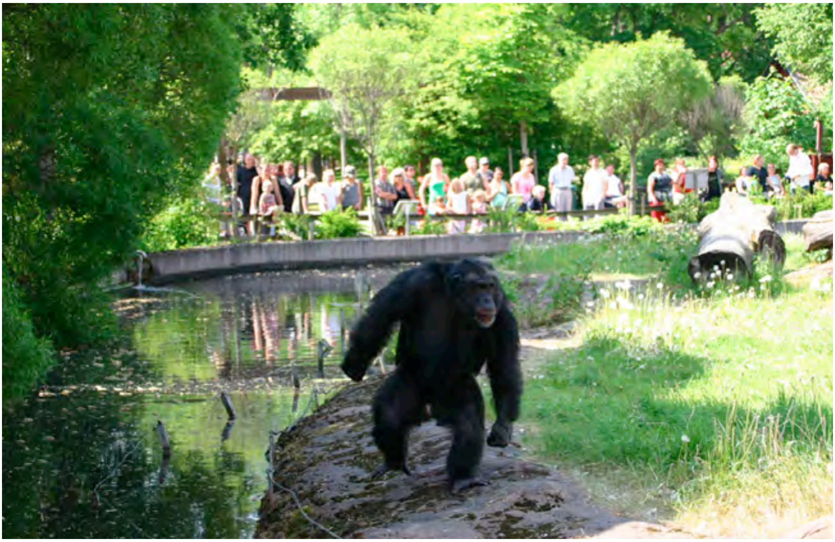

Figure 2. Displaying male chimpanzee. The male displays with a stone in his left hand. The forceful bipedal locomotion and the pilo-erection (hair on end) are signs of agitation

The chimpanzee has not been observed using stones or concrete in contexts other than throwing, and the behaviours have not been exhibited off-season when the zoo is closed and visitors are absent (50% of the yearly outdoor period is off-season). The purpose of the behaviours is further demonstrated by the fact that the discovered caches were always located at the shoreline facing the visitors' area; representing less than 25% of the island's circumference.

Planning, involving tool making, reveals a cognitive complexity not apparent in laboratory experiments. The production and use of concrete discs have been discovered or invented by the chimpanzee, as it had never been shown to him. The inferential chain, stretching from the detection of concrete hollowness to the offended visitors, comprises a noteworthy range of sequentially ordered advanced cognitive operations. This type of planning with tool making indicates a flexibility associated with mental pre-experience of an upcoming event [1]. The behaviours also hint at a parallel to human evolution, where similar forms of stone manipulation constitute the most ancient signs of culture. Finds as old as 2.6 million years suggest that hominins carried and accumulated stone artefacts on certain sites, presumably a case of future need planning [10].

Supplemental Data

Supplemental data are available at
http://www.current biology.com/supplemental/S0960-9822(09)00547-8.

Acknowledgments

I wish to thank the three senior chimpanzee caretakers for their time and devotion in the making of this report. I am grateful to Furuvik zoo that allowed research on such an unfavourable issue as stone-throwing animals. Thanks also to Tomas Persson for helpful comments on the manuscript.

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Supplemental Data: Spontaneous planning for future stone throwing by a male chimpanzee

Mathias Osvath

Supplemental Experimental Procedures

Subject and group composition

Santino, the male chimpanzee described in the report, was born in 1978 at Munich Zoo in West Germany. He was transferred to Furuvik Zoo in Sweden at the age of 5. He spent the 5-month quarantine period with a keeper, Ing-Marie Persson (IMP). He was then introduced to a group of chimpanzees. This consisted of 5 individuals: 4 females and 1 male. Two of the females and the male were the same age as Santino, and two females were adults. Another chimpanzee group was visible from the compound housing Santino's group. This group, including an adult male, two adult females and infants, was present for the first 4 years of Santino's residence.

Over the years, the composition of Santino's group varied, ranging between 4 and 7 individuals of mixed sexes and ages. When Santino became the dominant male at the age of 16, there was only one other male in the group. This male died within the first year of Santino's dominance, leaving Santino as the sole male. Soon after this, the occasional stone throwing began. Stone throwing or other stone manipulations had not been observed in Santino or the other individuals in the group prior to Santino's establishment of dominance. When Santino began to cache stones, he had been the only male in the group for 2 years. His behaviour has not been copied by the females, who seem to show little interest in the stone caches and concrete disc manufacturing.

Season

The public season of the zoo typically stretches from the beginning of June through the end of August. It is often open on weekends in

September and May. Depending on weather, the chimpanzees are typically given access to the outdoor compound for the first time each year in early April, and they often prefer not to go outdoors after the end of October. It is worth noting that the chimpanzees at this zoo encounter zoo visitors during only about 25% of the year.

Method

To obtain the data presented in the report, an unorthodox choice of methods within the field of animal cognition has been necessary. The stone throwing behaviours pose a serious risk of injury to zoo visitors. For ethical and legal reasons, it has therefore not been possible for the author to systematically follow stone and concrete ammunition from its gathering until its use in throwing. When the caretakers discover stone and concrete caches or come across the chimpanzee gathering or manufacturing ammunition, they must of course intervene to prevent stone throwing.

Despite these constraints, a large amount of data has been obtained. Perhaps most importantly, the first observations of the behaviour were systematically carried out by IMP, after a managerial decision. They aimed to establish the reasons for the increase in stone throwing and its relationship to the newly discovered stone piles. These observations are briefly presented in the report, and more extensively below. The description is based on discussions with the observer, corroborated with logs and staff meeting notes.

The second data acquisition method was through interviews. The behaviours described in the report – stone caching, disc manufacturing and throwing – have been observed by numerous zoo personnel, visitors and the author. Some have observed all of the behaviours and others have witnessed parts of them. The informants were however restricted to 3 individuals: the senior caretakers who witnessed the behaviours from their initiation and had since kept track of their development. The limitation of informants to 3 was done in order to ensure consistency and to minimise the potential risk of counting the same occasions more than once. Excluding observers, however, also means that the estimated frequencies of the behaviours are likely to be conservative.

The first observations

The first systematic observations were made in early June 1997. They were carried out in order to investigate whether the male chimpanzee actually gathered stones beforehand and later used the caches as ammunition depots. This suspicion had arisen among the caretakers after the dramatic increase in stone throwing at visitors, coupled with the discovery of stones along the shoreline, placed in piles.

One caretaker, IMP, placed herself in a veterinary room with windows looking out upon the chimpanzee island. From this viewpoint it was possible to overlook approximately 75% of the island. Just after the chimpanzee group was let out in the morning, at approximately 8:00 am, the caretaker took up position in the room. The first observations of the stone gathering were made on the first morning of observation. The male chimpanzee reached into the water, brought up several stones at a time, and placed them on the shore on 3 separate occasions. The stones were placed in well-separated locations, all of which faced the visitors' area. During this observational session, which lasted for approximately 2 hours before the zoo opened at 10:00 am, he was not observed to manipulate the stones further, and he did not throw any of them. The first display occurred before lunch. The chimpanzee grabbed stones from the piles and threw them into the crowd. The caretaker hurried to warn and protect the visitors, at the same time trying to usher the chimpanzee inside. Eventually the caretakers succeeded in getting the male inside. On this occasion, 10 stones were found outside in the visitors' area, but there is reason to assume that more stones were thrown, as some stones usually fall into the water. When the caretakers went out to the island to remove any remaining stones, they could find none, indicating that all had been thrown during the display. The male chimpanzee was let out after lunch and did not make any more displays that day.

On the following four days, the caretaker positioned herself in the veterinary room when the chimpanzees were let out in the morning. On each of these days, she observed the male chimpanzee gather 3 to 4 piles of stones and some individual stones. Parts of the island were not visible from the room and it is possible that more stones were gathered than was observed. The displays occurred before lunch, when the first crowds assembled. On these days, the caretakers tried to usher the chimpanzee inside before the visitors arrived. This proved impossible as there where no other means than verbal commands to force the unwilling ape inside. Instead, the caretakers stood guard to warn the visitors of getting too close. On 3 of the 5 days, there were remaining stones to be found on the island's shore. These stones were found in what seemed to be untouched piles, and as a few individual stones. After these 5 days a staff meeting was held where it was decided, based on the observations, not to let the chimpanzees outdoors before the zoo opened.

In the following period, when the chimpanzee was only let out after the zoo's opening, he did not gather any stones. He did, however, display, often in relation to the gathering of the first crowd of the day. This lends itself to at least 2 conclusions. One is that the chimpanzee is highly limited in acquiring stones during displays if they are not cached – which is the most probable reason for caching. The other is that the urge to display appears strongest in the initial daily interactions with the visitors. It therefore makes sense to acquire one's stones before opening hours. After some weeks, the chimpanzees were let outdoors before opening hours again. This was done for practical zoo maintenance reasons. The chimpanzee resumed his caching on some occasions, but less frequently than in early June. After mid-July, the caching stopped, and all forms of dominance displays decreased.

According to interviews with the caretakers (see below), there has been a recurring pattern in the chimpanzee's behaviour since the first season of observations: he starts to cache in early June when the season begins; he usually displays in the first half of the day; and the urge seems to wear off after mid-July.

Interviews

Despite the large group of observers, the informants were restricted to three senior keepers. Two of the caretakers, IMP and Torsten Lönn (TL), had worked with the male chimpanzee on a daily basis since he arrived at the zoo. One caretaker, Annika Nielsen (AN), had worked with the chimpanzee since he was 10 years of age. All three observed the initial planning behaviour and have since been struggling with precautionary actions.

The informants were individually interviewed, following a pre-written questionnaire. After the interview sessions, the caretakers compared answers with each other and discussed them with the author acting as moderator and taking notes. There were no contradictions in the answers. The numbers of stone caches found were so high that the informants were unable to give a precise estimate. They agreed that several hundred had been cleaned off of the island since they first detected the behaviour. The number of times stone gathering had been observed was likewise difficult to estimate because of its high frequency. A conservative estimate of 50 times was agreed upon. The estimated number of caches per occasion and the number of stones in each cache were consistent among the informants (3-6 caches containing 3-8 stones, see Figure S1). The estimated number of observations that had been made of concrete disc manufacturing differed slightly. The caretakers agreed that this was probably a result of the fact that some had observed occasions that others had not. TL had observed at least 18 occasions, IMP had observed 5-10 manufactures and AN had seen the behaviour at least 5 times. The number of times per opening season that displays included stone throwing was estimated to be between 10 and 30 times. This figure depends on how successful the countermeasures were, which in turn was governed by the current staff resources at the zoo. The number of stones thrown per occasion is approximately 10 or more if the behaviour is not successfully breached. IMP described some occasions as “hail storms”. All three informants independently stated, with a high degree of certainty, that they had never seen a cache on the non-visitor side of the island. AN had once observed a cache placed close to the centre of the island, but on the visitors’ side of the concrete rock structures. From measures on the blueprint of the island it can be estimated that the length of the shoreline where the caches have been placed is less than 25 % of the total circumference of the island; the area of the caches position is harder to measure, it is however less than 10 %

of the total of the island. All informants were also highly certain that the chimpanzee was without exception calm during gathering, and always agitated when displaying. Informants agreed on the time of day and period of year during which the behaviours occurred. No one had ever seen caches during the off-season.

Figure S1. A representative pile, including concrete discs, produced by one of the caretakers (AN) in illustratory purpose.

Paper V

In spite of the common intuition that chronology is a basic property of autobiographical memory, the research reviewed demonstrates that there is no single, natural temporal code in human memory.

W.J. Friedman (Memory for the time of past events, 1993)

What should be compared in comparative mental time travel?

Mathias Osvath, Caroline R. Raby and Nicola S. Clayton

Roberts and Feeney [1] recently argued that tests of mental time travel (MTT) in animals must show that they are highly time specific in order to demonstrate qualitative comparability with human MTT. We suggest that such a demonstration, however interesting, would show only the ability to order more than one event temporally within the past or the future. Roberts and Feeney acknowledge that neither time nor place is an essential element of MTT. MTT as experienced by humans is rarely specific in absolute time. The temporal order of events need not be encoded into episodic memory traces and the perception of a chronological past depends on a process of active and repeated construction, which may include having to add a sense of pastness [2]. Although a sense of the past and the future is regarded as a defining factor of MTT [3], the precise time sequencing suggested by the authors is not.

A question at the core of the current comparative MTT-debate is whether or not animals are capable of so called autonoesis, the awareness of being subjectively involved in the represented past or future events [3]. Such representations are enabled by the episodic cognitive system. The authors argue that our studies on great apes and corvids [4–6], which suggest MTT into the future, could instead be explained by the animals using the semantic memory system and not the episodic. In their view, the animals know facts and, based on these, take actions that affect their future, without projecting autonoetically into that future. For example, they argue that scrub-jays apparently making provision for a future meal might simply have a predisposition to cache foods in novel locations. It is not clear to us why scrub-jays might evolve such a propensity, which seems less adaptive than making provisions for future needs. In any event, Raby and Clayton have argued that using the semantic system does not, per se, preclude the use of future thinking [7].

Nonetheless, the studies as they stand seem to fulfill the current criteria for non-linguistic displays of MTT [3,8,9]. One study seems to be a particularly clear case of non-human MTT [5]. The chimpanzee who calmly gathers, manufactures and stockpiles projectiles for future agitated throwing, exhibits most, if not all, such criteria. Roberts and Feeney's alternative account is unconvincing, as the behaviours are flexible, including tool making and spatial caching strategies, and crucially, exhibit dissociations between psychological states.

There is another possibility, namely, that behaviour indistinguishable from MTT could be exhibited without autonoesis, although is not clear how one could distinguish between the two in the absence of agreed behavioural markers of consciousness in non linguistic animals. Similar behaviours can be produced by different underlying systems. This is especially pertinent when comparing evolutionarily convergent cognition, such as that of phylogenetically distant corvids. We suggest that the field of comparative MTT requires terminology beyond the concepts of human psychology to illustrate the potentially broader character of future oriented cognition in the natural world.

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Paper VI

First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth.

J.F. Kennedy (May 25, 1961)

Prospection as a cognitive precursor to symbolic communication

Peter Gärdenfors and Mathias Osvath

What are the significant forces behind the evolution of language?

Explaining how language evolved involves answering two quite distinct scientific questions (Bickerton 2003; Tomasello 2003). The first is why humans have developed a system of *symbolic* representation as a basis for much of their communication. The second is why this system has acquired the structural characteristics of the *syntax* of extant human languages. In this paper, we focus on the first question.

Homo sapiens is the only species we know to have a symbolic language. If one believes that language has come into existence according to the principles of evolutionary theory, there should be some selective advantage that has promoted the development of language among humans. Recently, a popular approach has been that language arose as a result of increased *social interaction*, for example as a consequence of increasing group size (Dunbar 1996) or as some form of ritualization (Deacon 1997; Knight 1998b).

However, despite all the merits of these proposals, they have problems explaining why humanlike symbolic language has *no*t evolved among other apes or animals (Bickerton 2002: 209; Gärdenfors 2004: 237; Johansson, Zlatev, and Gärdenfors 2006). As a matter of fact, the social interaction among many species is highly developed. Bickerton (2002: 210) argues: "When a complex and unique development occurs in only one species, the most logical conclusion is that the selective pressure driving that development must have been unique to that species. Thus the strength of social intelligence in other primates argues against, not for, social intelligence as the force behind the emergence of language."

The upshot is that some other evolutionary forces behind the evolution of language must be identified – forces that have only applied to the hominin line. One factor that has been surprisingly neglected in the discussions of the evolution of language is the difference in the *ecology* of the early hominins and the other apes (Bickerton 2002). Partly following Osvath and Gärdenfors (2005), we shall argue that the Oldowan culture, 2.6–1.5 million years ago, constituted an ecological niche containing evolutionary forces that generated symbolic cognition. The long-ranging character of this culture made the use of prospective cognition, that is the skill to plan for future events and needs, beneficial. The second step of our argument is that advanced prospective cognition made communication about future goals advantageous for the hominins. The evolutionary gain of being able to communicate about referents that are not yet present is that collaborative forms of long-term planning become possible. Symbolic communication is an efficient way of solving problems concerning cooperation about future goals – more efficient than iconic miming, as we shall argue. The basis for our hypothesis is the notion of prospective cognition. This will be the topic of the following section. In the following section, we outline the Oldowan culture and explain why this culture contained the selective pressures for evolving a symbolic language. The next section discusses the new possibilities for cooperation, in particular cooperation about future goals, which open up once prospective cognition is present. Cooperation is enhanced by communication, and in the final section we argue that a symbolic system is required for efficient cooperation about future goals.

Prospective cognition

One way to understand the functions of most of the higher forms of cognition is to analyze how humans and other animals represent various things and states, in particular the surrounding world and its possibilities. There is an extensive debate in the literature on what is the appropriate meaning of "representation" in this context (see e.g., Roitblat 1982; Vauclair 1990; Humphrey 1993; Gärdenfors 1996, 2003; and Grush 1997). In order to give intelligible descriptions of many phenomena in animal and human cognition, it is useful to distinguish between two kinds of mental representations: *cued* and *detached* (Gärdenfors 1996, 2003).

A *cued* representation stands for something that is present in the current external situation of the representing individual. In general, the represented object need not be actually present in the situation, but it must have been triggered by something in a recent situation. Also delayed responses, in the behaviorist's sense, are based on cued representations according to this characterization. When, for example, a particular object is categorized as food, the animal will then act differently than if the same object had been categorized as a potential mate. We are not assuming that the individual is, in any sense, aware of the representation, only that there is some generalizing factor that determines its behavior.

In contrast, *detached* representations may stand for objects or events that are neither present in the current situation nor directly triggered by some recent external situation. A memory of something that can be evoked independently of the context where the memory was created would be an example of a detached representation. For example, consider a chimpanzee who performs the following sequence of actions: walks away from a termite hill, breaks a twig, peels its leaves off to make a stick, returns to the termite hill, and uses the stick to "fish" for termites. This behavior seems very difficult to explain unless it is assumed that the chimp has a detached representation of a stick and its use. A detached representation is something the individual can utilize regardless of whether what it represents is present or not.

A detached representation can even stand for something that does not exist at all. For example, our imaginative worlds are full of centaurs, unicorns, elves, and trolls – about which we easily communicate – although they do not truly correspond to any sensory impressions we have received. Being able to use a detached representation requires that one can suppress the sensations one has at the moment; otherwise they will come into conflict with the representation (Glenberg 1997). This capacity places new demands on mental capacities. The suppression of information appears to be managed by the frontal lobes of the brain, which are the parts that have expanded most rapidly during the evolution of the hominins. The frontal lobe is believed to be crucial for skills such as planning and fantasizing and for the so-called "executive functions" of self-control (Hughes, Russell, and Robbins 1994).

This notion of detachment is related to Hockett's (1960) "displacement" which is one of the criteria he uses to characterize what constitutes a language. But the notion of a detached representation is not identical with his. The reason is that the definition of "displacement" (Hockett 1960: 417) includes the following: "Any delay between the reception of a stimulus and the appearance of the response means that the former has been coded into a stable spatial array, which endures at least until it is read off in the response." This description has a clear behaviorist ring to it, and it means that every signal that is not an immediate reaction to a stimulus would be counted as an example of ”displacement” according to this criterion.

The collection of all detached representations of an organism and their interrelations will be called *the inner world* of the individual. There are strong indications of that humans have more complex inner worlds than other animals (Gärdenfors 2003). Gomez (2004: 20) argues that the prolonged immaturity in the children of apes and in particular humans results in a greater flexibility in forming representations which in turn leads to greater cognitive and behavioral flexibility.

The ability to envision various actions and their consequences is a necessary requirement for an animal to be capable of planning. Following Gulz (1991:46), we will use the following criterion: An organism is planning its actions if it has a representation of a goal and a start situation and it is capable of generating a representation of partially ordered set of actions for itself for getting from start to goal. This criterion presupposes representations of (1) goal and start situations, (2) sequences of actions, and (3) the outcomes of actions. The representations of the actions must be detached, otherwise the organism has no choice. According to our characterization, planning therefore presupposes an inner world.

There are several clear cases of planning among primates and in other species (see e. g., chapters 5, 7, 8 and 9 in Ellen and Thinus-Blanc 1987; Gulz 1991: 58–61; Byrne 1995; Suddendorf and Corballis 1997; and Hauser 2000). The termite-fishing chimpanzee mentioned earlier is one such example. It is important to distinguish between immediate planning for present needs and prospective planning for future needs. (Gulz (1991) calls prospective planning anticipatory planning, a term that we also used in Gärdenfors (2003) and Osvath and Gärdenfors (2005)). The crucial distinction is that for an individual to be capable of prospective planning it must have a detached representation of its future needs. In contrast, immediate planning only requires a representation of the current need.

It has been commonly argued that the prospective skill for planning for future needs is exclusive to humans (e.g. Gilbert and Wilson 2007; Köhler 1921, 1925; Premack 2007; Roberts 2002, 2006; Suddendorf and Corballis 1997, 2007; Tulving 2005). This is sometimes called the Bischof-Köhler hypothesis. However this hypothesis can no longer be upheld in the light of recent findings. Great apes are not only able to select tools for future use (Mulcahy and Call 2006), but also to save tools that have currently been used to satisfy a desire (Osvath 2009a). Even tool making for future needs has been documented in chimpanzees (Osvath 2009b) Perhaps most importantly, great apes are able outcompete current drives in favor of future ones as well as being able to envision future events (Osvath and Osvath 2008). Interestingly enough, this ability to plan for future needs also seems to have evolved independently in the avian taxon of corvids (Correia, Dickinson, and Clayton 2007; Raby et al. 2007).

It is notoriously difficult to obtain unequivocal observations of such prospective planning behaviors in the wild. However, this difficulty should not be confused with the absence of the cognitive skill. Rather, the lack of observations might be a result of the complexity of the situations in the wild involving factors we cannot control for. Hence it is most often appropriate to give leaner interpretations of behaviors seen in the wild than to ascribe the animal a skill for planning for future needs. On the basis of this we want to make two general points. The first is that the most reliable sources of information we have about planning for future needs are the artifacts surrounding future-oriented behaviors. These are found in abundance when it comes to humans, but are very scarce when it concerns non-hominin species. Given the experimental results of great ape and corvid planning abilities, this indicates that the skill for planning for future needs did not start evolving as an answer to an artifactual culture (as we have argued elsewhere: Osvath and Gärdenfors 2005). It is not unlikely that prospective cognition indeed has its roots in advanced social life (Osvath and Gärdenfors 2007). This leads to the second point: The skill for future planning was to substantial extent already present in the first hominins as they shared their last common ancestors with the rest of the great apes. This means that when the ecological situation changed, this skill could be exploited in the survival strategies of the hominins.

Oldowan: a long-ranging culture

The appearance of the first sharp-edged stone tools in the archeological record roughly coincides with a series of other relevant events in the human evolution. Ice sheets started to grow in the northern parts of the world and Africa experienced deforestation and expanding savannas. The increased grasslands reduced the floral food resources for the hominins, as the savannah is only about half as productive as a tropical forest. On the other hand, the production of herbivores on the savannah is almost three times as high, yielding a markedly larger mammal biomass (Leonard and Robertson 1997, 2000). These ecological changes resulted in selective pressures on the hominins that lead them to change their diet from predominantly vegetarian to more protein and fat based. The resulting culture is associated with the finds at Oldowan (Isaac

1982, 1984). The sharp stone edge appears to be a direct answer to this shift as even the earliest finds of Oldowan technology is associated with butchering (de Heinzelin et al. 1999; Semaw et al. 2003). It is also likely that the stone tools were used for woodworking and processing plant materials, as is indicated by a microwear analysis of 1.5 million-year-old Koobi Fora stone artifacts (Keeley and Toth 1981). Bickerton (2002: 213–214) argues that the savannah conditions forced the hominin to use a wider variety of food sources than the other primates and that these food sources were more transient and scattered than the predominantly vegetarian food sources exploited by the other primates. From this he concludes that the day ranges of the early hominins must have been larger than those of extant apes.

There is clear evidence that transport of the artifacts (at least the stone tools) was an important trait of the Oldowan culture (Toth 1985). Another important and distinctive feature in the new increased meat eating lifestyle is the accumulation of tools and bones (hominin meal leftovers) at certain places in the plio-pleistocene landscape. Although these accumulations have been interpreted in numerous ways, some assumptions are fairly undisputed: Stone tools or their raw material as well as pieces of carcasses were transported to these locations from kilometers away (Toth 1985; Plummer 2004).

Plummer (2004) summarizes the main components of the Oldowan culture as: (1) the manufacturing and use of stone tools; (2) the transport of artifacts (at least the stone tools); (3) the transport of pieces of carcasses; (4) and the use of accumulation spots. The most significant advantage of this culture is that it enabled a much wider exploitation of species that provided meat. The conglomerate of cultural and other environmental factors and their implications, behavioral and others, were causally intertwined in complex and intricate ways. It is not quite clear who manufactured the Oldowan tools, but Plummer (2004: 127) concludes his analysis by saying that *Homo habilis* was probably the maker between 2.3 and 2.0 million years ago and *Homo ergaster* between 2.0 and 1.6 million years ago.

The Oldowan lifestyle was in a way signified by an extension in time and space. For example, there were long delays between the acquisition and the use of the tool, as well as considerable geographical distances between the sources of tool raw material sources and killing sites. The fitness of the hominins in this niche would increase with adaptations for long ranging, as shown in the morphological remains. These morphological adaptations must also have been related to behavioral adaptations. We submit that the behavioral adaptations relied on prospective cognition. This cognition was most likely within the capacity of these hominins, because extant great apes also display such abilities. However, we submit that these cognitive skills became more important for the Oldowan hominins and had an obvious ecological use.

Our first example supporting this concerns the curated technology (Toth 1985) that is represented by the Oldowan culture. Plummer (2004) summarizes the curated characteristics as follows: "Oldowan was not simply an expedient technology: the repeated carrying of artifacts for use at different points on the landscape may reflect pressure to curate or economize, based on a current or projected need for stone." There certainly seem to have existed projected, that is, detached, needs within the Oldowan culture. It is not possible to know exactly where the next fresh kill will be found; it might be several kilometers away from nearest raw material source. Without sharp-edged stone tools in the immediate vicinity, a carcass would loose much of its value for a hominin. The big predators and scavengers would probably not allow enough time for the hominins to locate the nearest tool source, not to mention all the extra energy that would be lost in a non-planned search for tools. This problem could be solved by habitual stone carrying.

However, just carrying tools is a strategy that lacks flexibility. If a hominin can envision which area it is going to patrol, then it can decide if it has to bring raw material for tools or not. Transporting something that would not be needed is uneconomic. The strategy of accumulating stones of the preferred raw material in areas where no stones can be found is beneficial, since long periods of haphazard transports are avoided. This strategy becomes even more effective if one keeps track of the resources available in a given accumulation spot: neither letting it run out of stones nor wasting energy by carrying stones to an already abundant supply. Prospective cognition would solve this task swiftly. Another aspect of Oldowan culture seems to be the saving of a tool (or a core) after it has been used once. It is needless to point out the great economy in such behavior. With prospective cognition one "knows" that there will be a need for the tool in the future as well. Prospective cognition opens up a very flexible selectivity that can be used with high precision and efficiency depending on one's current imagined goal related to a future need.

Our second example of prospective thinking that had selective effects concerns division of labor. This form of prospective cognition could in fact be used to turn the group of hominins into a virtual Swiss army knife, which would benefit every individual within the group. A division of labor within the group could solve a multitude of needs at once. Some individuals might carry throwing stones, some might carry sharp edges and others could carry water or wooden tools. It is a way of optimizing the carrying resources of the group, which is probably already burdened with carrying infants. Such cooperation requires a shared goal outside the scope of the immediate drive state, and, more importantly, it is dependent on an advanced form of communication.

Another form of division of labor associated with the *Homo ergaster/erectus* is a sexual division in foraging. Scavenging or hunting was arguably mainly a male concern. One of the simple reasons for this is that hominin children could not maintain the speed and endurance of the adults in the presumed patrolling activities, as children are less energy efficient (see e.g., Plummer 2004) and of course slower and weaker. Children were most probably close to their mothers, who must have been somewhat more stationary due to care of their infants. And among other things, the bipedal foot of hominin infants (and the loss of bodily hair) makes it impossible for them to cling to their mothers. Unlike other primates, the hominin mothers therefore had to use their arms to carry their babies (see e.g., Savage-Rumbaugh 1994). Females would thus have been engaged in a "slower" foraging, such as gathering high quality plant food. This kind of division is a common foraging strategy in modern tropical foraging societies where males provide most of the energy and protein to the diet (Kaplan et al. 2000).

The modern human form of hunting and gathering is highly dependent on prospective cognition. The individual must in some sense be able to imagine other individuals currently outside his or her immediate sensory scope doing their part of the job. The strategy does not allow the individual an immediate consumption of all the obtained food, even if there is a drive state that signals hunger. Individuals must also at some times ignore high-energy food and focus on their task, hunting or gathering (a standard procedure for most hunter-gather foragers), in order to achieve the main goal – a variable and nutritious meal. These examples present some reasons why complex prospective cognition was beneficial within the Oldowan culture. Once the period of Acheulean tools is reached, beginning about 1.5 million years ago, it is apparent that prospective cognition was in full use. Overall, it could be said that prospective cognition fits well with the lifestyle of the hunter/scavenger-gathering and highly energy consuming *Homo ergaster/erectus* (Plummer 2004: 128). Hominins used an already existing cognitive capacity to cope with the changing ecological requirements. It is not unlikely that the new demands chiseled out a more fine-tuned and complex prospective cognition. However, it should be noted that the prospective skill is obviously not a cognitive necessity when dealing with savannah conditions. Many animals use different kind of strategies. Nevertheless, it seems as the most efficient adaptation for these primates was to use prospection and planning.

Collaborating for future goals

Humans as well as some animals cooperate in order to reach common goals. There are many ways of cooperating, some of which are not cooperation in the literal sense of the word. Among these one may count more or less instinctive coordination of behavior, such as it emerges among termites building hills or honeybees gathering food. At the opposite side of the scale, we find human cooperation, depending on elaborate long-term planning and negotiation (Gärdenfors 2007).

The hominin life on the savannah opened up for many new forms of cooperation for future goals. For example, Plummer (2004: 139) writes: "Given that body size often predicts rank in the carnivore guild, an individual *Homo habilis* would likely not have fared well in a contest with many of its contemporary carnivores. Competition with large carnivores may have favored cohesive groups and coordinated group movements in *Homo habilis*, cooperative behavior including group defense, diurnal foraging (as many large predators preferentially hunt at night) with both hunting and scavenging being practiced as the opportunities arose, and the ability (using stone tools) to rapidly dismember large carcasses so as to minimize time spent at death sites."

For many forms of cooperation among animals, it seems that representations are not needed. If the common goal is present in the actual environment, for example food to be eaten or an antagonist to be fought, the collaborators need not focus on a joint representation of it before acting. If, on the other hand, the goal is detached, that is, distant in time or space, then a *common representation* of it must be produced before cooperative action can be taken. For example, building a shared dwelling requires coordinated planning of how to obtain the building material and advanced collaboration in the construction. In general terms, cooperation about future goals requires that *the inner worlds of the individuals be coordinated*.

To show the evolutionary importance of cooperation for future goals, Deacon (1997: 385–401) suggests that the first form of symbolic communication is marriage agreements, that is, deliberate commitments to pair bonding. He argues that there was strong evolutionary pressure in hominin societies to establish relationships of exclusive sexual access. He says (Deacon 1997: 399) that such an exclusive sexual bond "is a prescription for future behaviors." Even though we do not know of any evidence that marriage agreement was the first form of symbolic communication, we still find this example interesting in the discussion of early prospective cognition. A detached pair-bonding agreement implicitly determines which future behaviors are allowed and not allowed. These expectations concerning future behavior do not only include the pair, but also the other members of the social group who are supposed not to disturb the relation by cheating. Anybody who breaks the agreement risks punishment from the entire group. Thus in order to maintain such bonds, they must be linked to social sanctions. With the aid of some form of ritual, one can mark out that there exists a loyalty bond for the rest of the group and that the appropriate sanctions are now in function. It should also be noted that episodic memory is required to be able to *refer* to the established loyalty bond later on, by miming or by speech, and to remind group members of the sanctions (Atran 2002: 159–160).

A marriage is a special case of a *contract*. Creating contracts is an advanced form of cooperating for future goals so it is no wonder that it is a uniquely human activity. The reason for this that a contract presumes that both partners have a "theory of mind": If we agree that I shall deliver a duck tomorrow in exchange for the axe you have given me now, I believe that you believe that I will deliver the duck and you believe that I believe that our agreement will then be fulfilled, etc. Furthermore, a contract depends on the possibility of *future* sanctions: If I don't deliver the duck, you or the society will punish me for breeching the agreement.

The need for symbols in communication about future goals

Symbolic language is the primary tool by which agents can make their inner worlds known to each other. In previous work (Brinck and Gärdenfors 2003; Gärdenfors 2003, 2004; Osvath and Gärdenfors 2005), it has been proposed that there is a strong connection between a lifestyle dependent on prospective cognition and the evolution of symbolic communication. In brief, the argument is that symbolic language makes it possible to efficiently *cooperate about future goals*.

Language is based on the use of representations as stand-ins for entities, present or just imagined. Use of such representations replaces the use of environmental cues in communication. If somebody has an idea about a goal she wishes to attain, she can use language to communicate her thoughts. In this way, language makes it possible for us to *share visions* about the future. The question that has to be answered is why symbolic communication is necessary for this kind of communication.

Tomasello (2003: 95) defines symbolic communication as the process by which "one individual attempts to manipulate the attention of, or to share attention with, another individual. In specifically linguistic communication this attempt quite often involves both (a) reference, or inviting the other to share attention to some outside entity (broadly construed), and (b) predication, or directing the other's attention to some currently *unshared* features or aspects of that entity." As we shall see below, we cannot fully accept this definition. One aspect that is missing in his characterization is that, depending on the character of the "outside entity," different cognitive demands on the individual whose attention is manipulated will be relevant. To understand the differences, one must distinguish between (1) entities that are present in the shared environment, (2) entities that are not present in time or space but about which there is some common knowledge, and (3) entities that are unknown to the other individual. Communication about future goals often involves entities of the third kind.

Depending on which type of entity is communicated about, different minimal forms of communication are required. It becomes very natural to map the three kinds of entities to be communicated about to Peirce's (1931–1935) triad of index, icon and symbol:

(1) If the entity is present, then *indexical* communication, for example pointing, is sufficient. In general, animal communication consists of signals, referring to what is present at the moment in the environment, be it food, danger or a mate. This form of communication does not presume that the signaler ascribes any mental representation of the communicated object in the mind of the receiver. It is important to note that this kind of communication does not require any form of symbols. (This is why we do not fully accept Tomasello's definition presented above.) Consequently, as long as all

> communication concerns present entities, there will be no evolutionary pressures for the use of symbols.
>
> (2) If the communicated entity is not present, direct signaling will not work. If I want to refer to a deer that I saw down by the river yesterday, merely pointing will not help, nor will a call signal. This form of communication clearly requires detached representations. *Iconic miming* may establish the reference, but only if the signaler and receiver have sufficient *common knowledge* about the indicated entity and there are sufficient cues from previous communication or the environment to make it possible for the receiver to identify the object. (This would be a case of what is called triadic miming in Zlatev, Persson, and Gärdenfors 2005). When the relevant entity is an action, this form of communication works particularly well. By using icons, one agent can show another how to act in order for the two of them to reach a common goal. Icons can work as an imperative, urging the receiver to "Do like this!" (Brinck and Gärdenfors 2003).
>
> (3) The most difficult type of communication concerns *novel* entities that do not yet exist. Collaboration about future goals may often fall within this category. Here the signaler can neither rely on common knowledge about the entity, nor on cues from the environment. Iconic communication might work in exceptional cases, but we submit that it is for this kind of communication that *symbols* prove their mettle. For example, if I have come up with an idea about how to build a new kind of defense wall around our camp, it is very difficult to see how this can be communicated by miming alone. In particular, if the communication involves the predication of Tomasello's definition above, that is, directing the other's attention to some currently unshared features or aspects of that entity, symbols seem to be crucial (see also Dessalles, 2007). Such a predication process will also require the productivity and compositionality of a symbolic system.

In this characterization we use "symbolic communication" in a basically Peircian way, meaning that the act is conventional and breaks up compositionally into meaningful sub-acts that relate systematically to each other and to other similar acts (Deacon 1997; Zlatev, Persson, and Gärdenfors 2005). This form of communication is, as far as we know, uniquely human. In this context it should be noted that Tomasello's (2003: 95) definition of symbolic communication that was presented above also covers what we call indexical and iconic cases.

An important feature of the use of symbols in cooperation is that they can set the cooperators free from the goals that are available in the present environment. Again, this requires that the present goals can be suppressed, which hinges on the executive functions of the frontal brain lobes. The detached goals and the means to reach them are picked out and externally shared through the symbolic communication. This kind of sharing gives humans an enormous advantage concerning cooperation in comparison to other species.

Again, we can refer to the role of contracts. Agreeing on a contract involves a form of prospective cognition. For example, when promising to give you a duck tomorrow in exchange for the axe you are offering me now, I must consider the possibility of future punishment. A contract is therefore a kind of cooperation about the future. Forming the agreement that constitutes the basis of a contract involves an advanced form of communication that may be difficult to achieve without using symbols.

We view the advantages provided by cooperation about future goals to be a strong evolutionary force behind the emergence of symbols. More precisely, our thesis is that there has been a co-evolution of cooperation about future goals and symbolic communication (cf. the "ratchet effect" discussed by Tomasello [1999: 37–40]). However, without the presence of advanced prospective cognition, the selective pressures that resulted in symbolic communication would not have emerged.

Conclusion

Prospective cognition is a key feature in the cognition of humans and is essential for language and other behaviors identified as unique for our species. This cognitive trait is fundamental in cooperation for future goals as well as for symbolic communication. We have argued for the use of prospective planning in the Oldowan culture, partly based on transport over extended space and time.

The second part of the argument is that the new ecological factors within the Oldowan artifactual culture together with the use of prospective cognition opened up for new forms of cooperation involving future goals concerning non-existing entities. Such cooperation has resulted in selective advantages for the individuals within cooperative hominin groups. The new forms of cooperation created a need for a communication in order to share visions about the future goals. We have argued that the required form of communication is symbolic since this form makes it much more efficient to communicate about detached needs and goals. In support of this, Peirce (1931–1935: 4.448) writes: ”The value of a symbol is that it serves to make thought and conduct rational and enables us to predict the future.”

The evolutionary relationships between cooperation, symbolic communication, and prospective cognition are probably intertwined in complicated coevolutionary processes. The pre-Oldowan hominins were probably on the brink of symbolic communication. Most of the cognitive prerequisites were in place due to previous selective pressures. Merely a push in the symbolic direction was needed. Such a nudge was facilitated by the conditions of the Oldowan culture. Coherent with evolutionary theory, this suggests that there was a gradual shift into symbolic cognition, in contrast to explanations relying on discontinuity (e.g. Bickerton 1990).

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